Adventures in FFT

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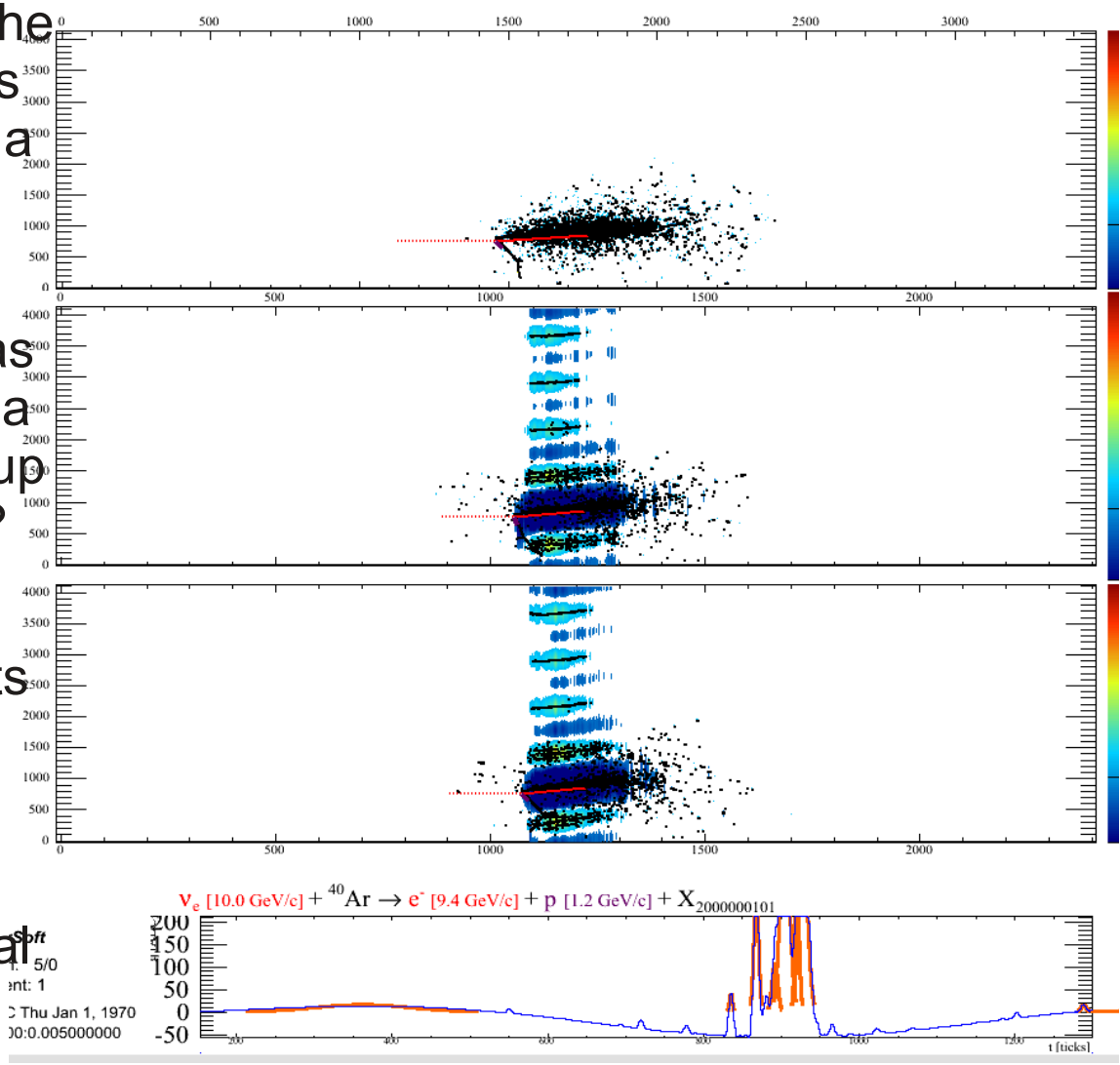
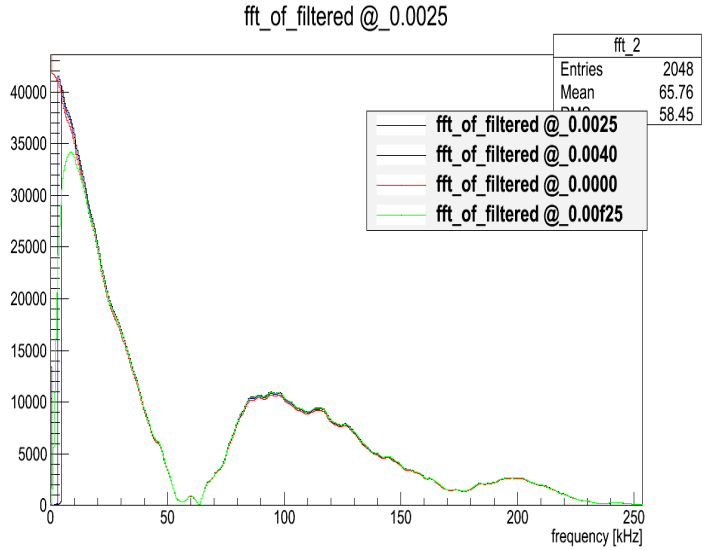
How I got into this

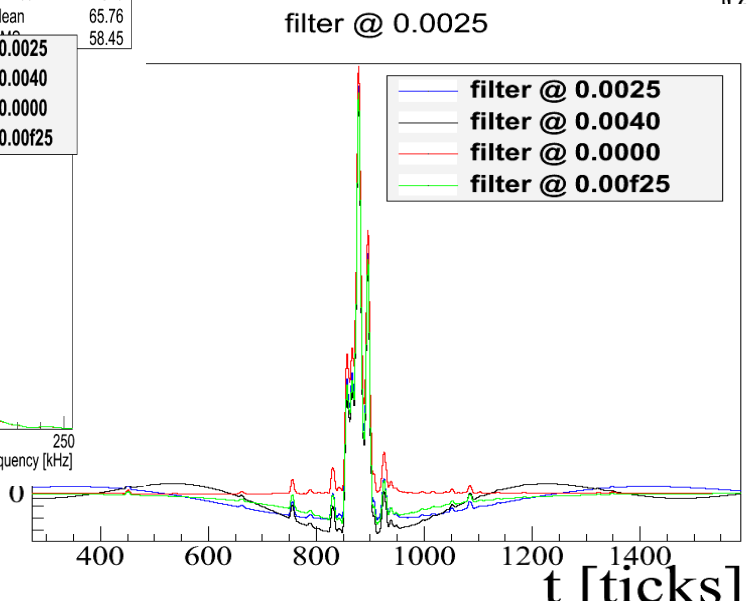
- I was running the reconstruction for events to be used for a hand scan in the MicroBooNE geometry. The problem is that the ringing+undershoot becomes a serious problem in a 10 GeV neutrino event in the induction plane.
- The outer bumps, (misreconstructed as hits) could probably be eliminated by a hitfinder threshold plus parameter setup that excludes events too wide in time?
- This does not solve cases, where the undershoot goes below 50 ADC counts as in the event here. Trouble with showers.
- the hitfinder threshold becomes badly defined. It can easily miss possible real hits, even with the threshold set for ArgoNeuT

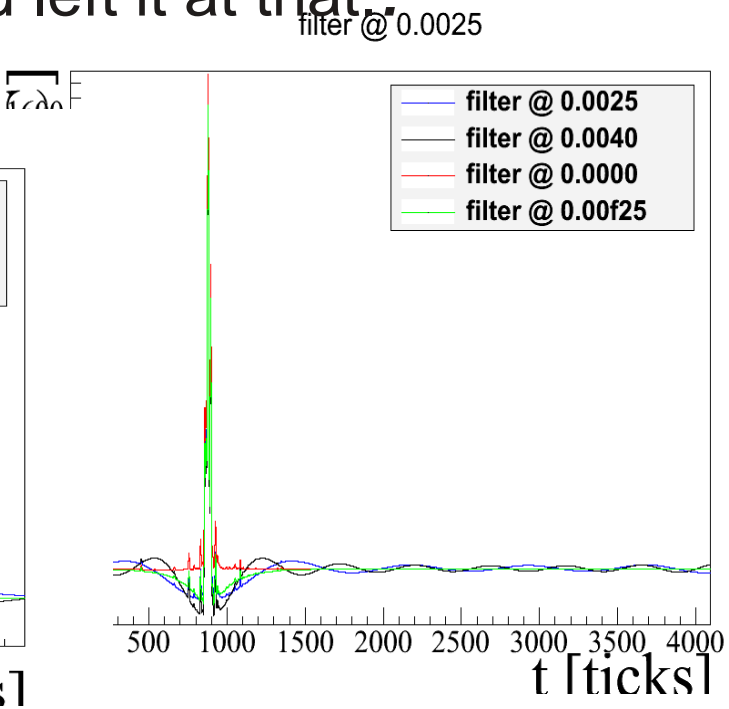


“Solution” to that problem

- Following Herb's suggestion I started looking at the filter function.
- It turned out that it was the filter function itself that caused the bumps and undershoot.
- The bumps are an effect of the square cutoff of the function.
- The undershoot remains whenever there is a cutoff above zero (even if you put in a smooth high pass filter)
- So I put in a (x>0) in the filter function and left it at that...

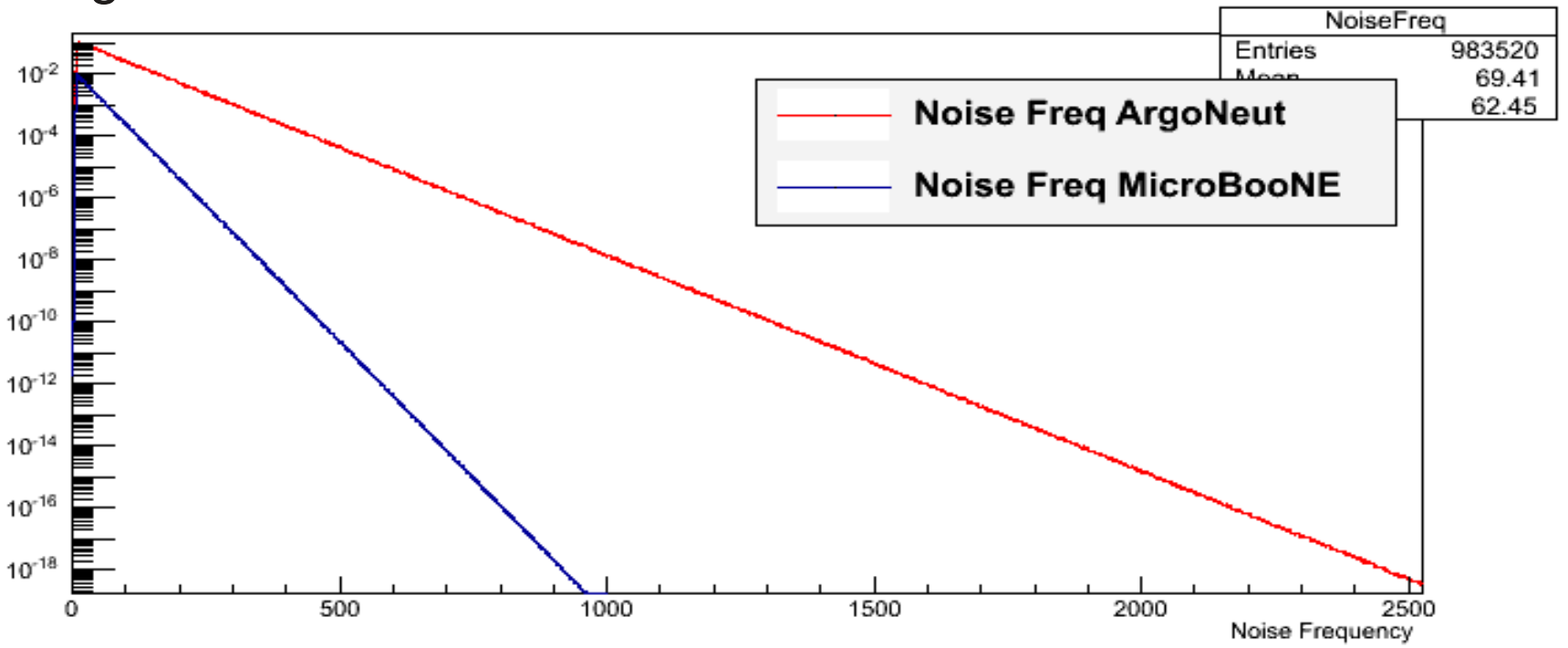




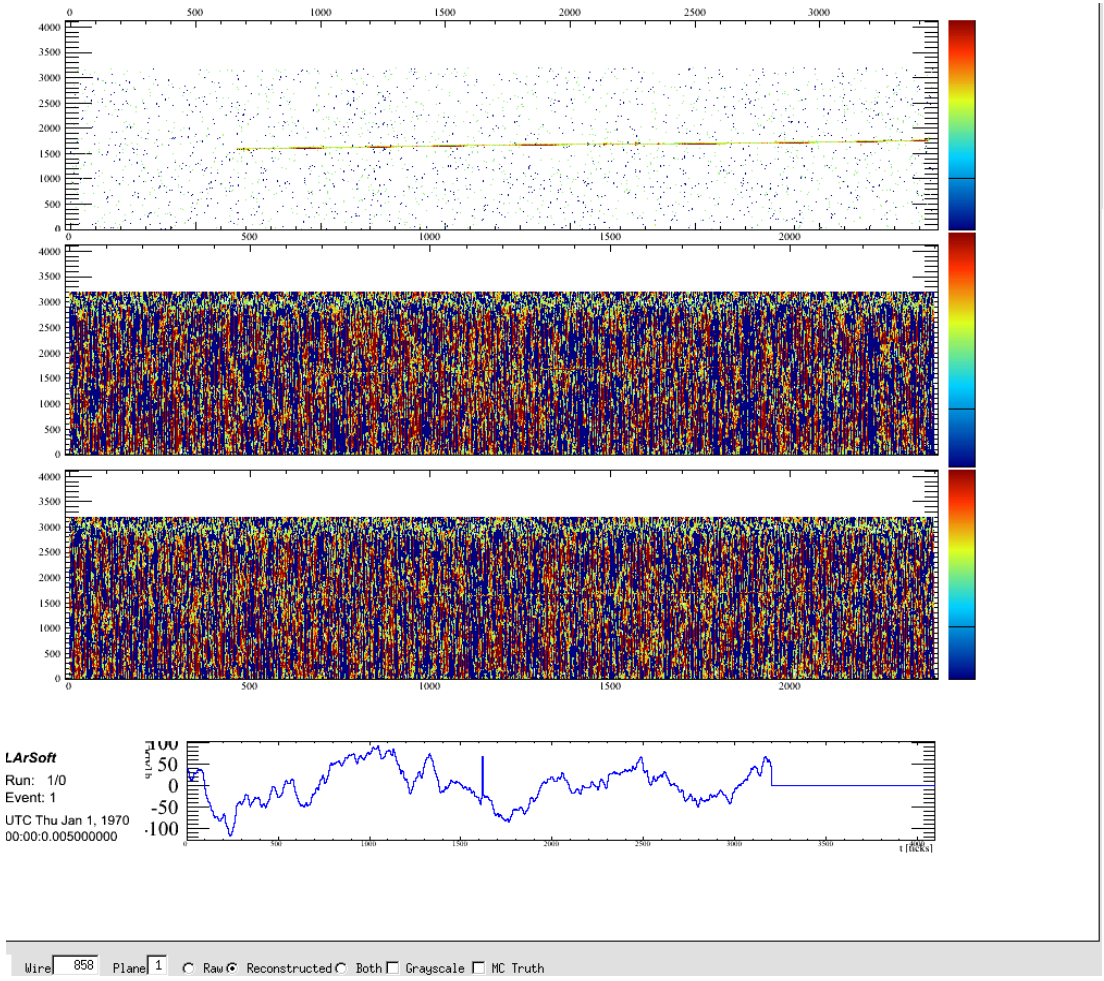


Adding Noise

- Needed it to get a new Hitfinder Threshold to see what gets caught into showers.
- Noise has been turned down to zero, when we changed to the real sampling frequency in uBooNE electronics because it blew up.
- I thought this was a result of the noise exponentials blowing up, so I modified the noise spectrum for uBooNE and raised the amplitude back again:



What I got: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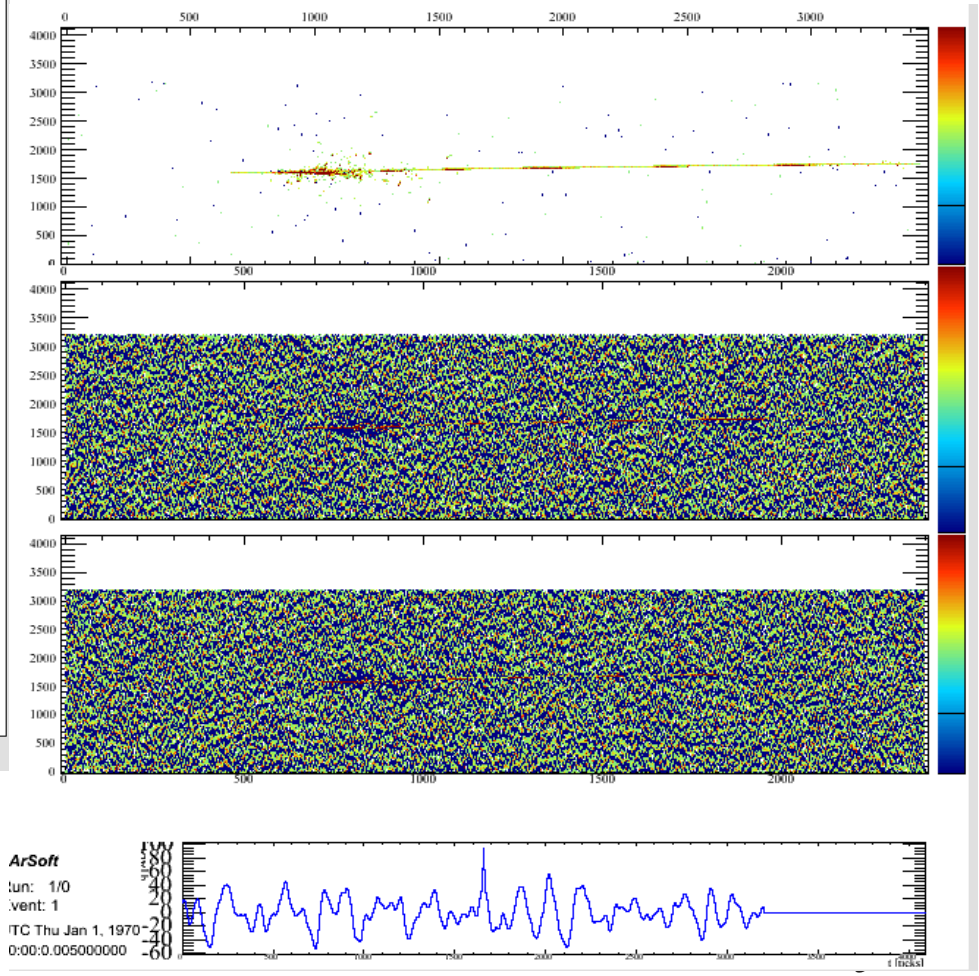
Wire 858 Plane 1 Raw Reconstructed Both Grayscale MC Truth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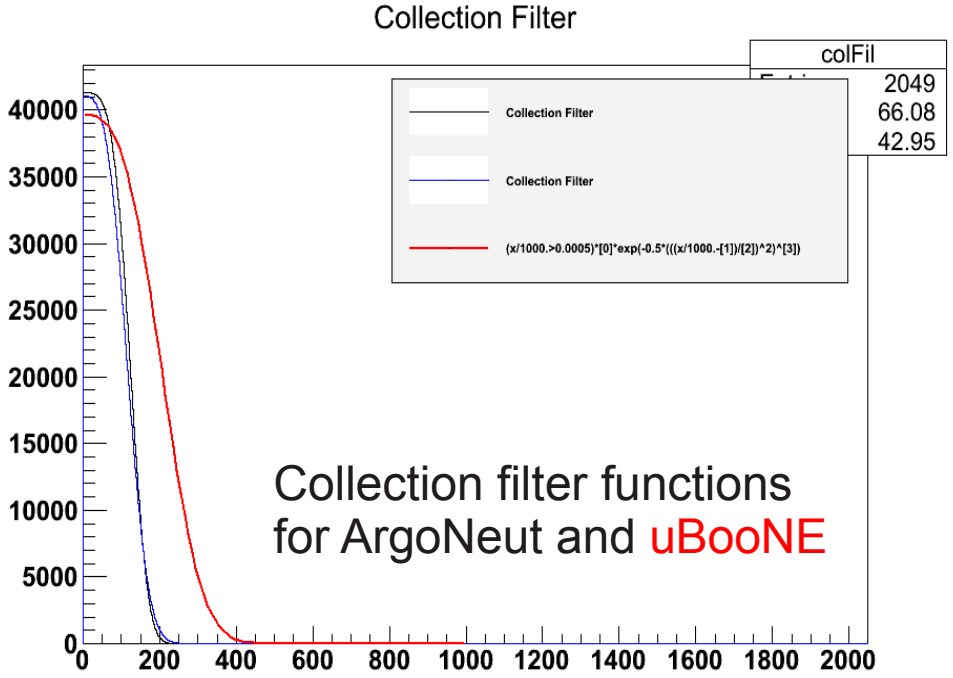
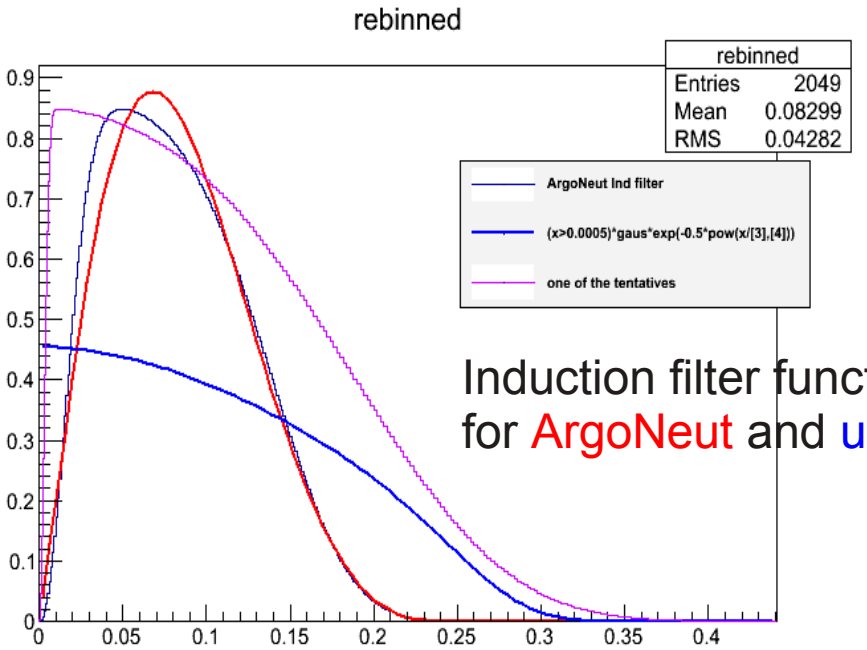
Back to filter functions and Deconvolution Kernels

(big thanks to Glenn for pointing me in the right direction)

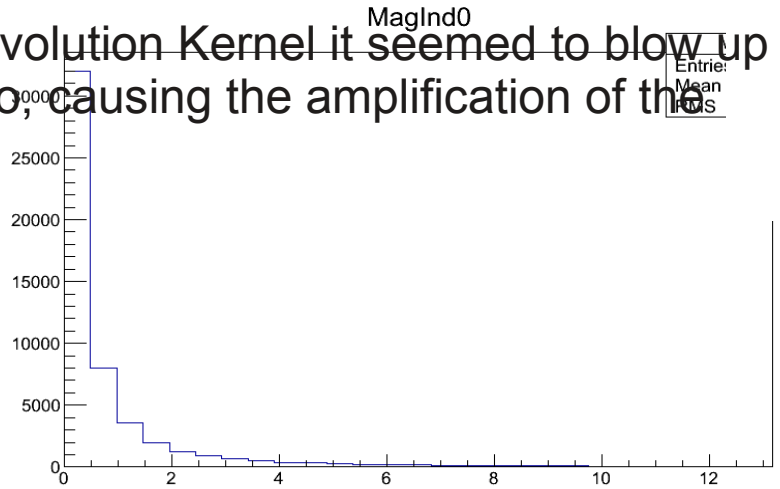


Collection filter functions for ArgoNeut and uBooNE



Induction filter functions for ArgoNeut and uBooNE

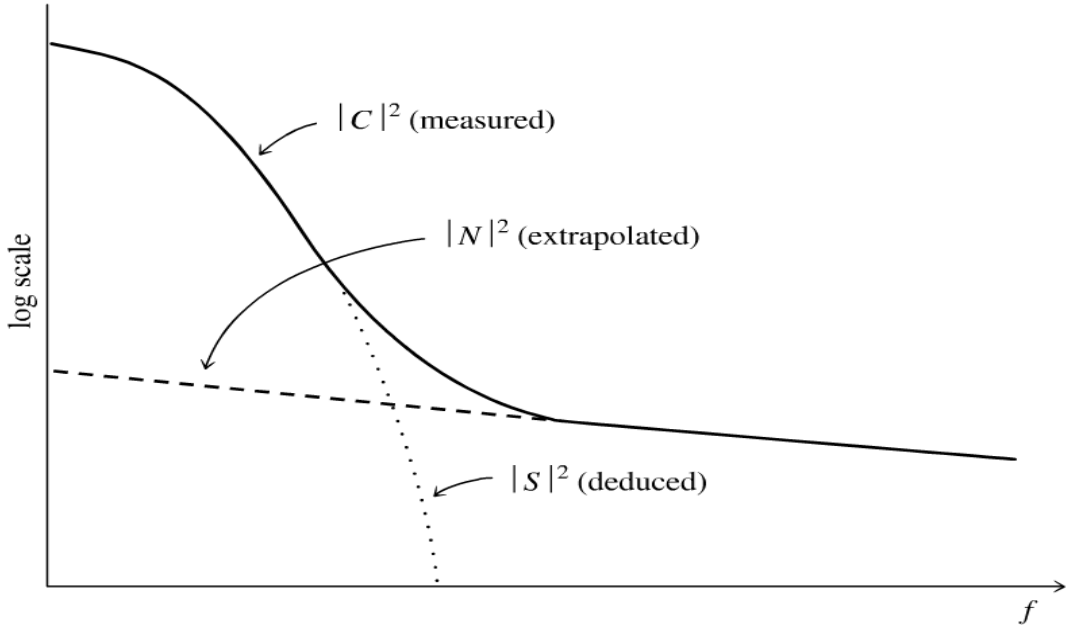
The Deconvolution Kernel it seemed to blow up around zero, causing the amplification of the noise.



A bit of theory
(from Numerical Recipes)

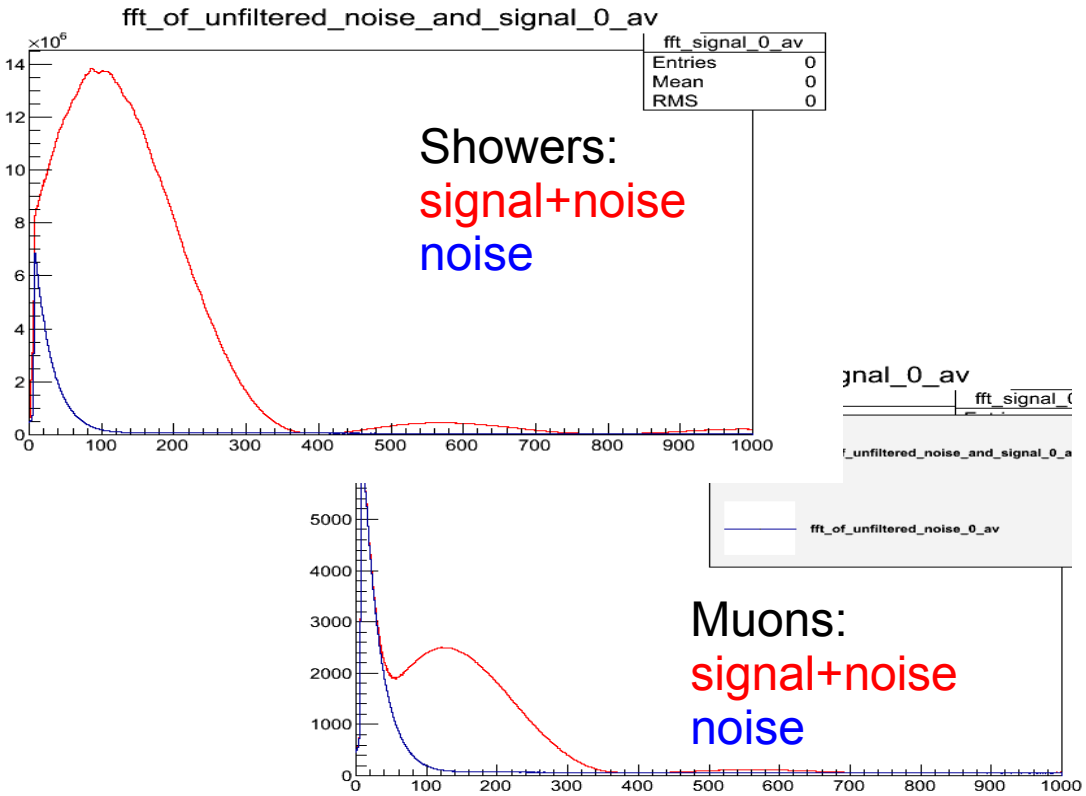
- To filter out noise, you need a filter function. Turns out, that there is an easy way to calculate it and it should be close to the optimum filter. The Wiener Filter. $\Phi(f) = \frac{|S(f)|^2}{|S(f)|^2 + |N(f)|^2}$

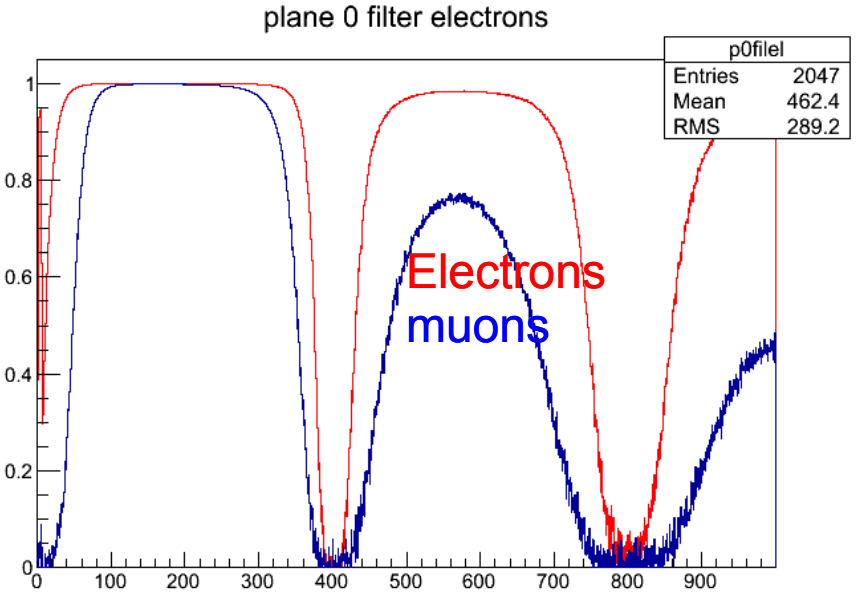
- The trick is that: $|S(f)|^2 + |N(f)|^2 \approx |C(f)|^2$



In our case:

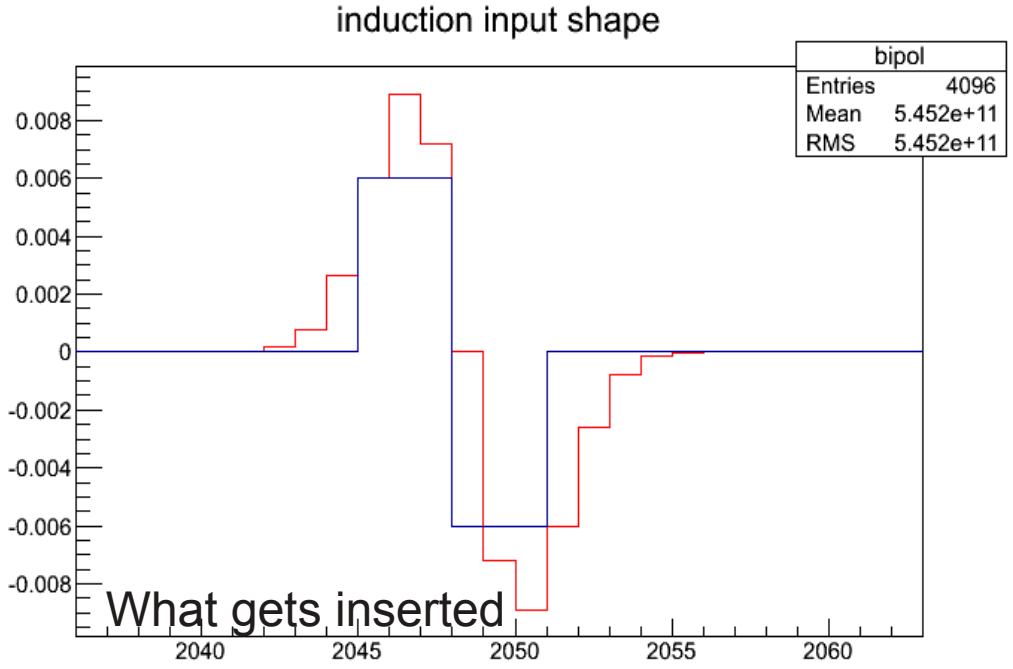
- Ran 20 events – 6GeV muon and 10 GeV electron shower
- Took 200 wires in noise region and signal region, FFT'ed them and summed the result up in total histograms. Used this to calculate the Wiener Filter as in: (C^2 – N^2)/(C)^2 where C is presumably S+N.
- The filter is different for high charge density events than for single track muons. Plus it's periodic in freq. Space. That is not right,

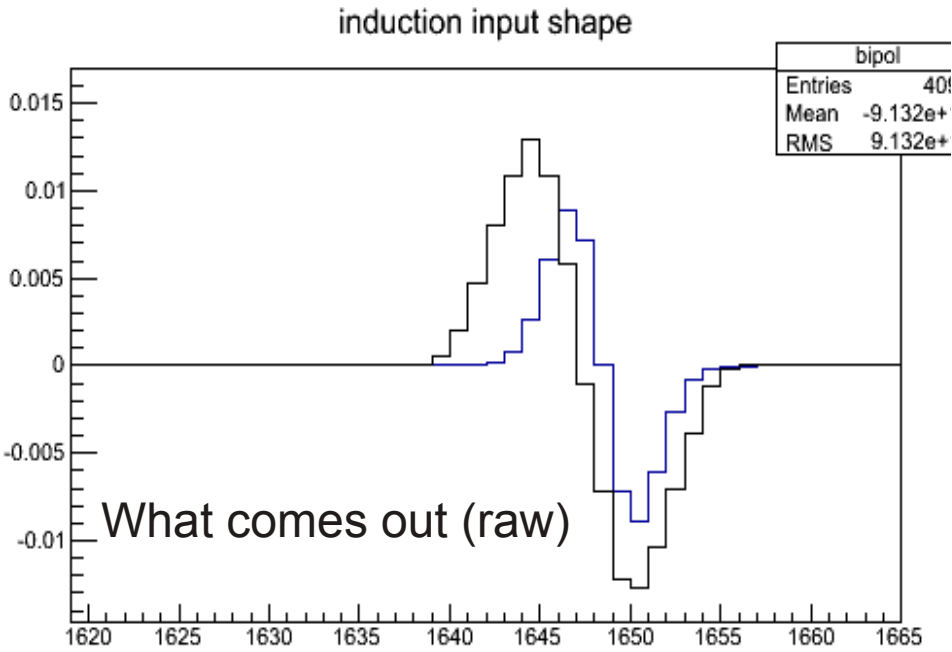




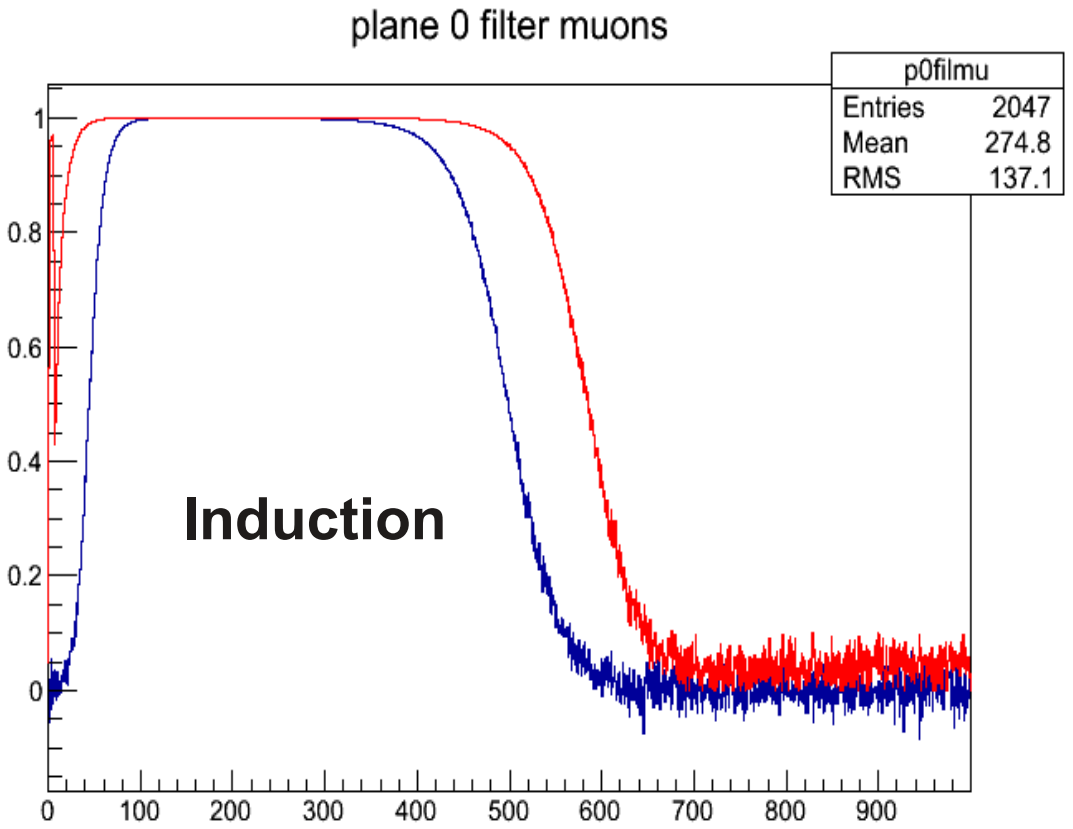
“Deux ex Machina”

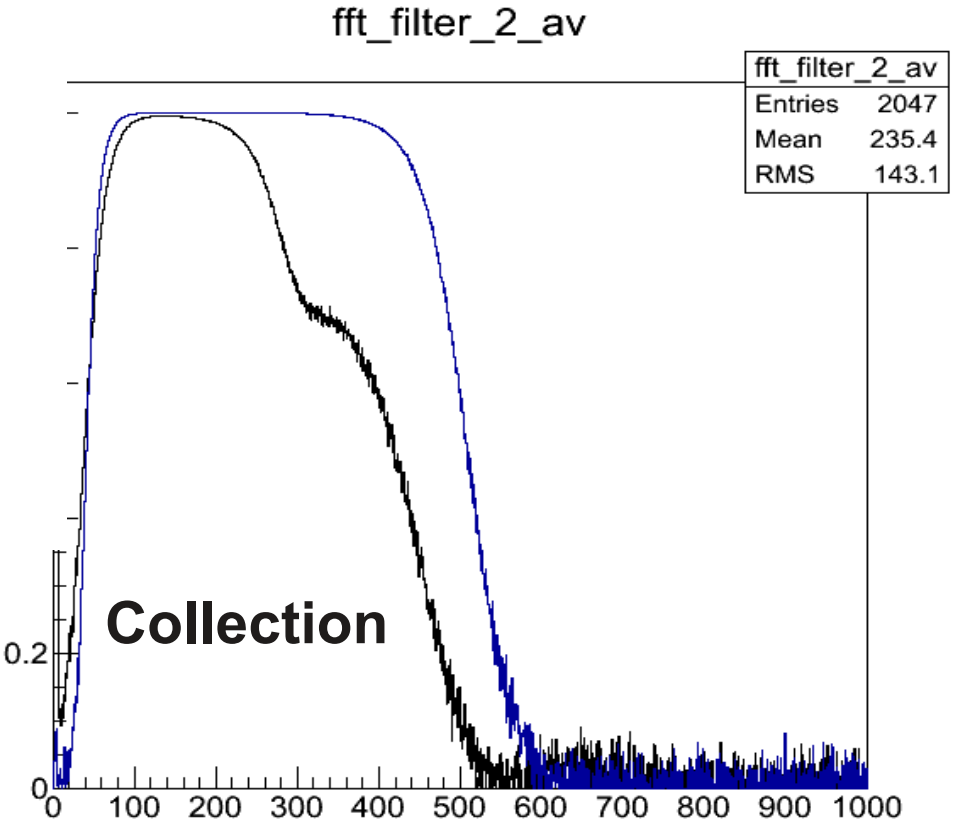
- Found a piece of code written by B. Page, which had less rectangular (more realistic?) shapes of the induction and collection signals:
- Also tried inserting his collection signal shape





Filter with new shapes:

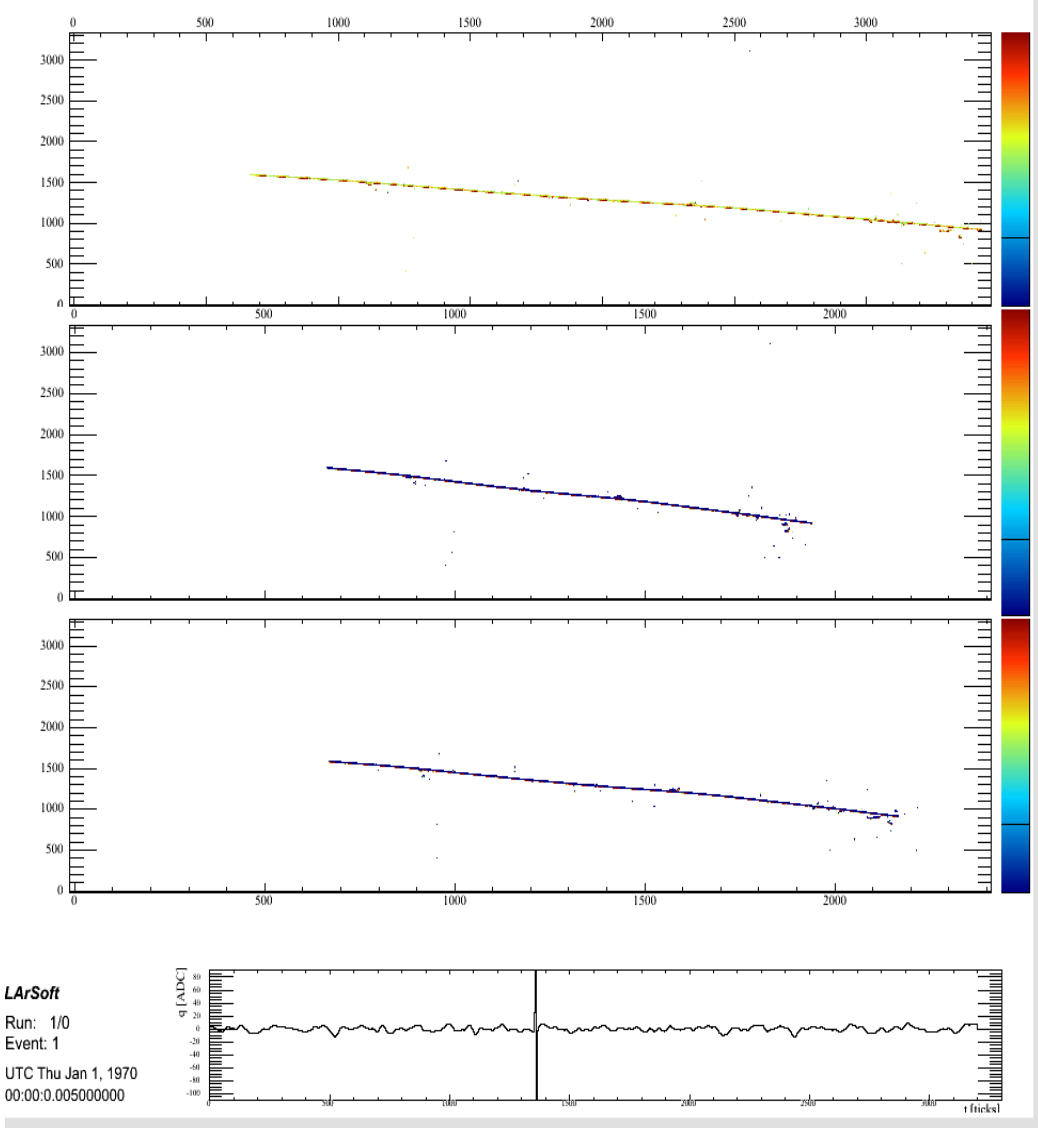


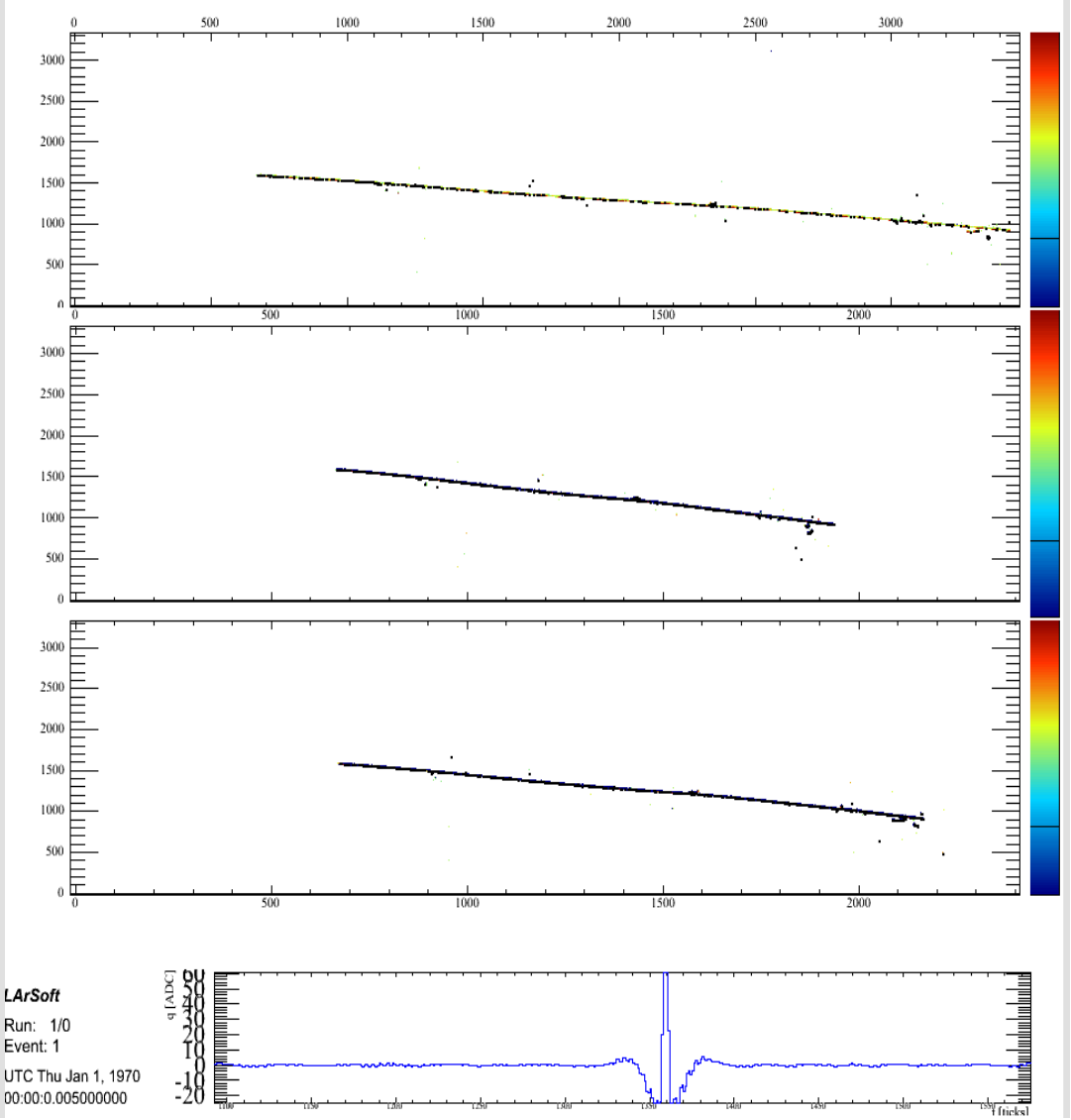


The Muon version fits reasonably with a "New Zealand Ecology Logistic 2" function. Implemented that into the code.

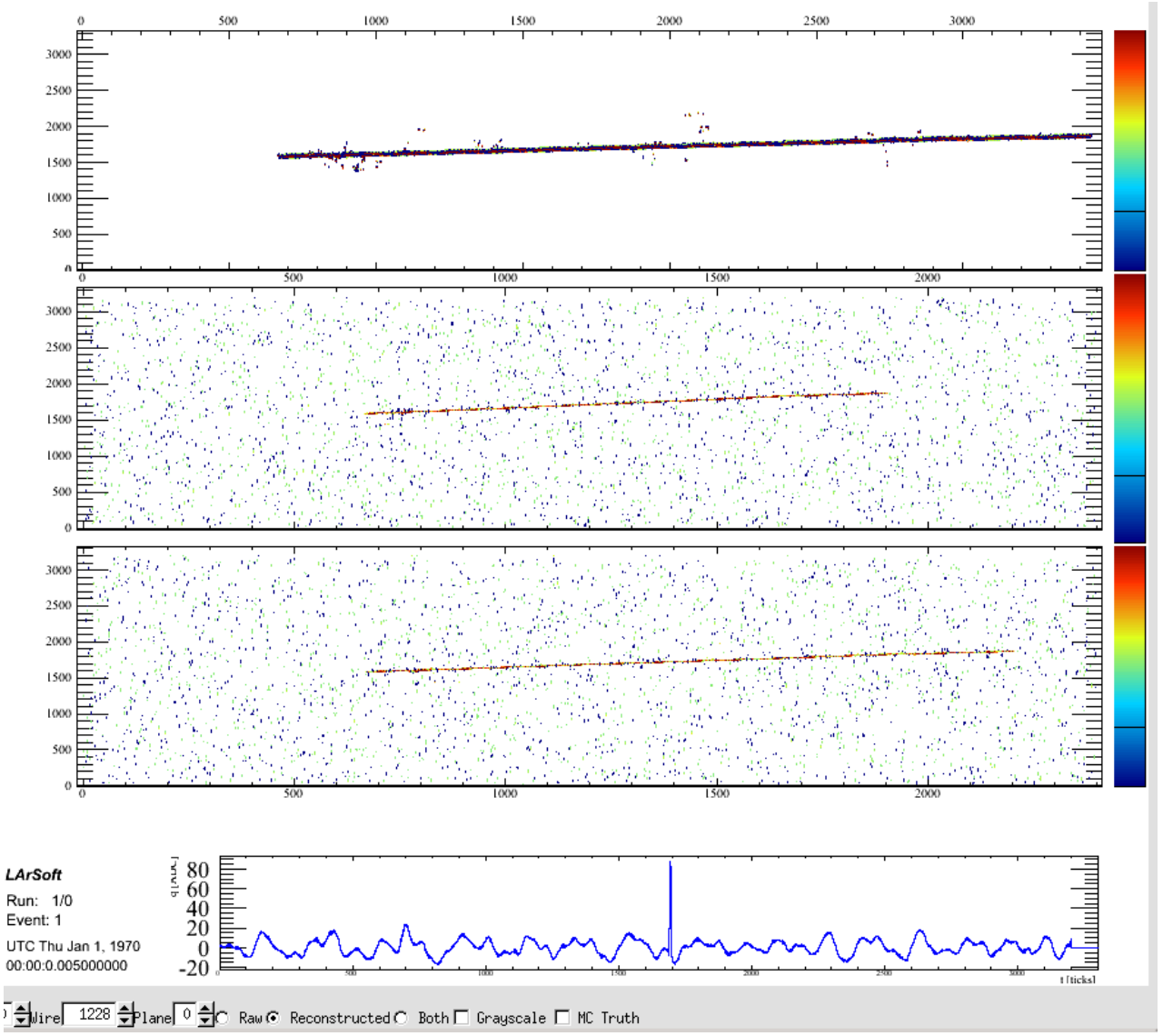
Results!

- I am now able to introduce the noise and obtain reasonable noise levels after the signal shape deconvolution. I am using the muon event generated filter and we will probably have to live with an undershoot. We should think whether caldata should not be correcting for this.



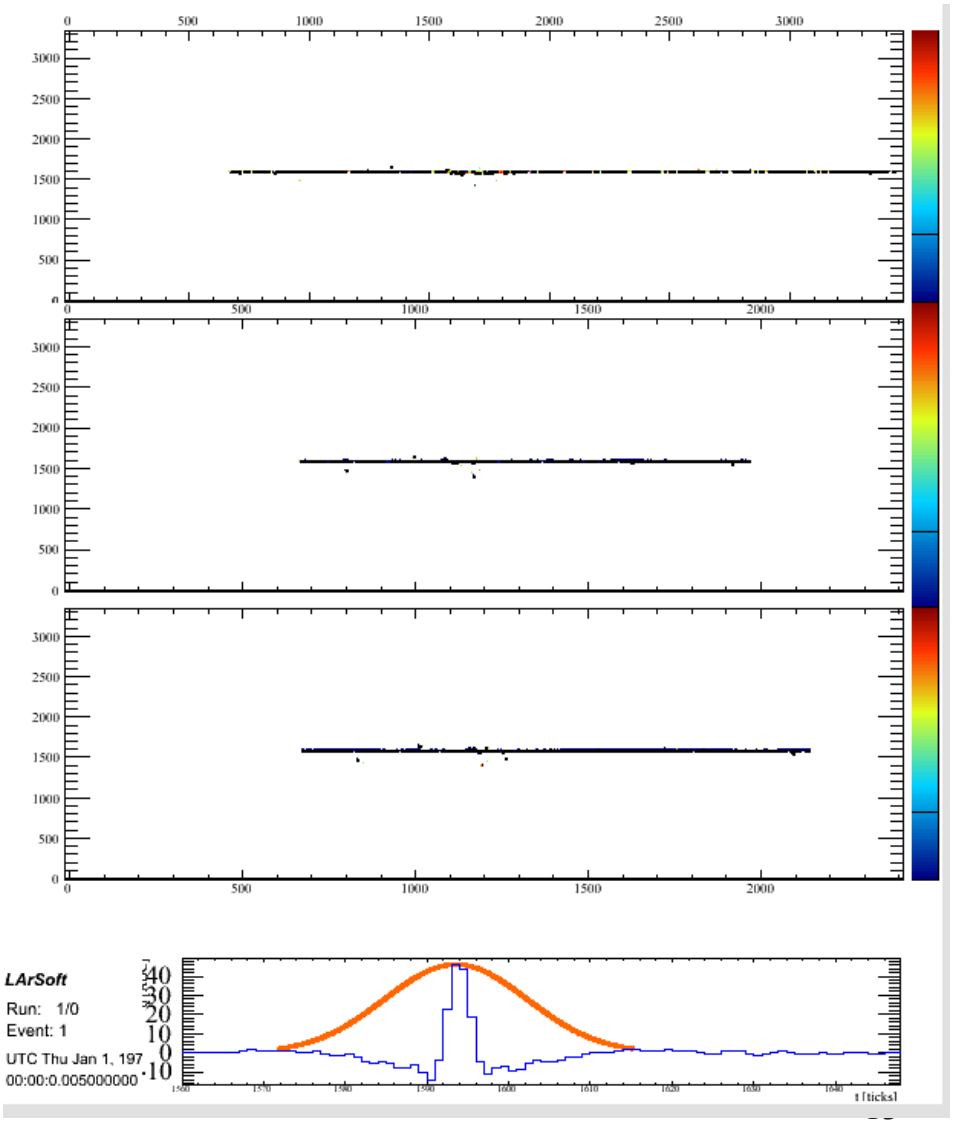


Why I'm not using the electron generated filter:



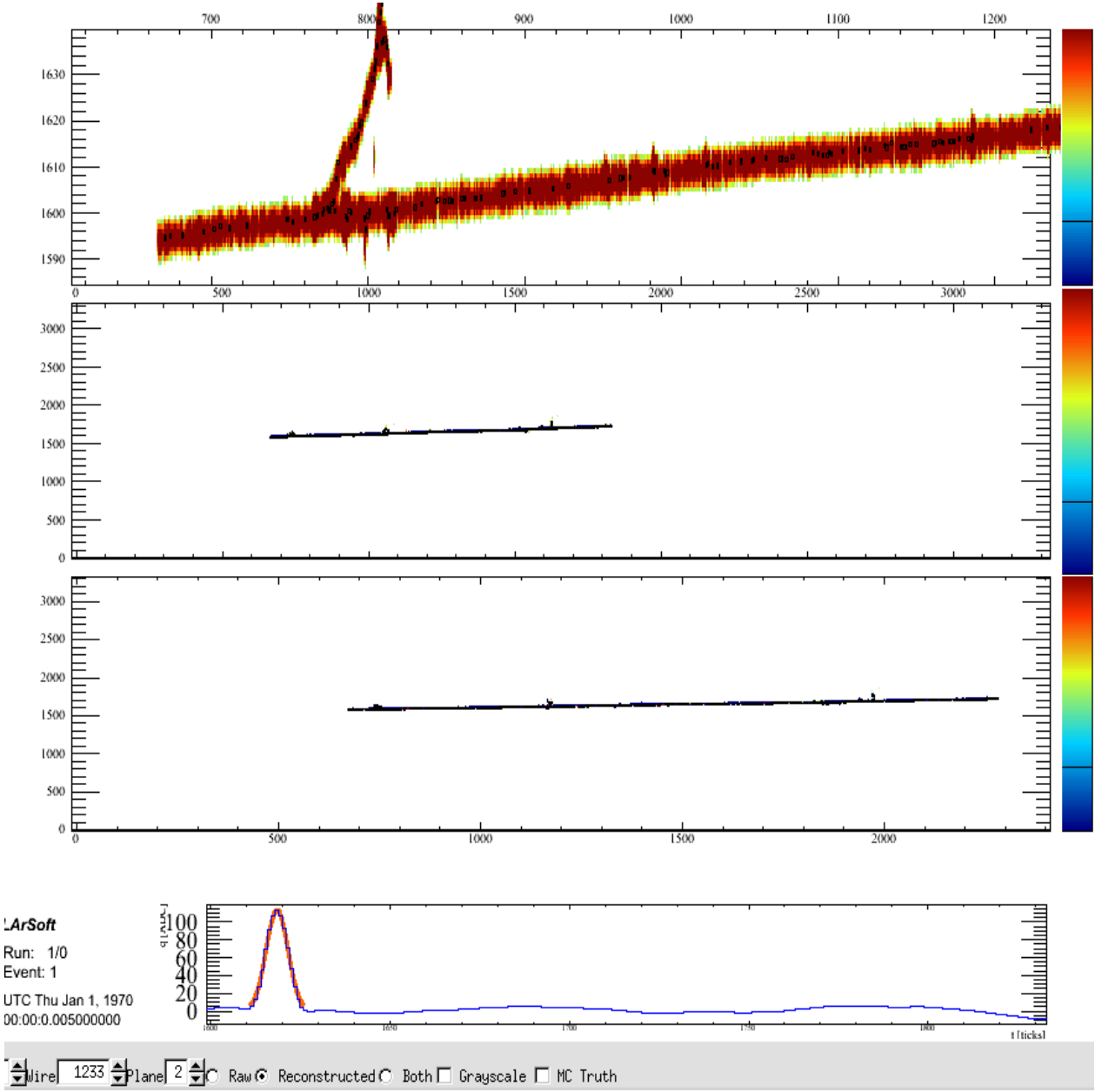
All is not well, however.

- If I introduce the filter for collection (cutting out the zero frequencies) I end up with an undershoot. This troubles the hitfinder. (Induction as well)



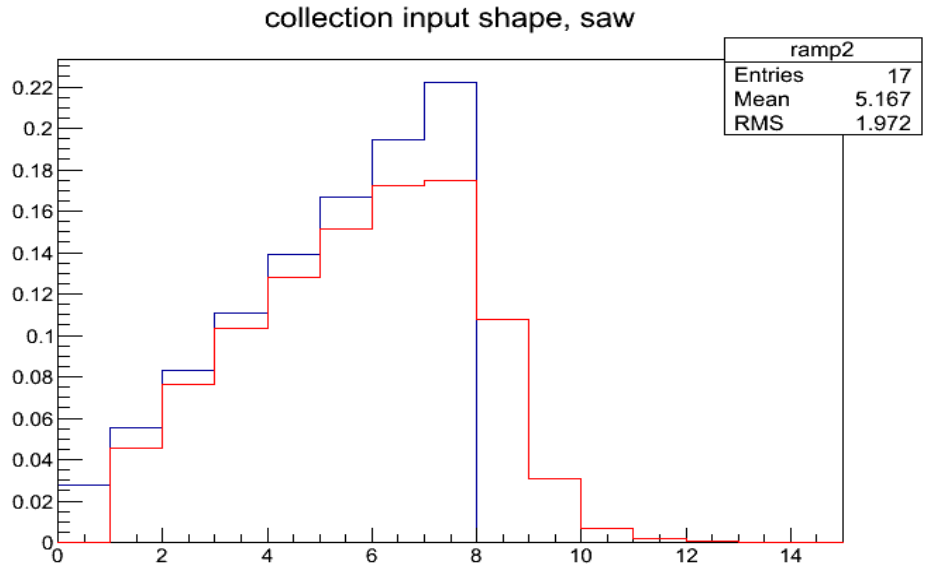
All is not well, however (2).

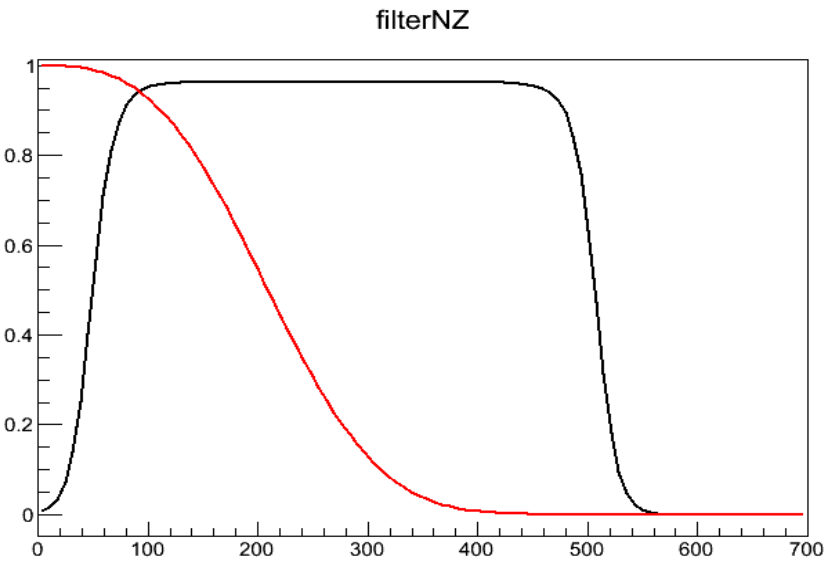
- It seems we can live with the old shape of the filter function, however the hitfinder still has problems. New signal shape is the cause?
- We would also need to recheck the calorimetry.



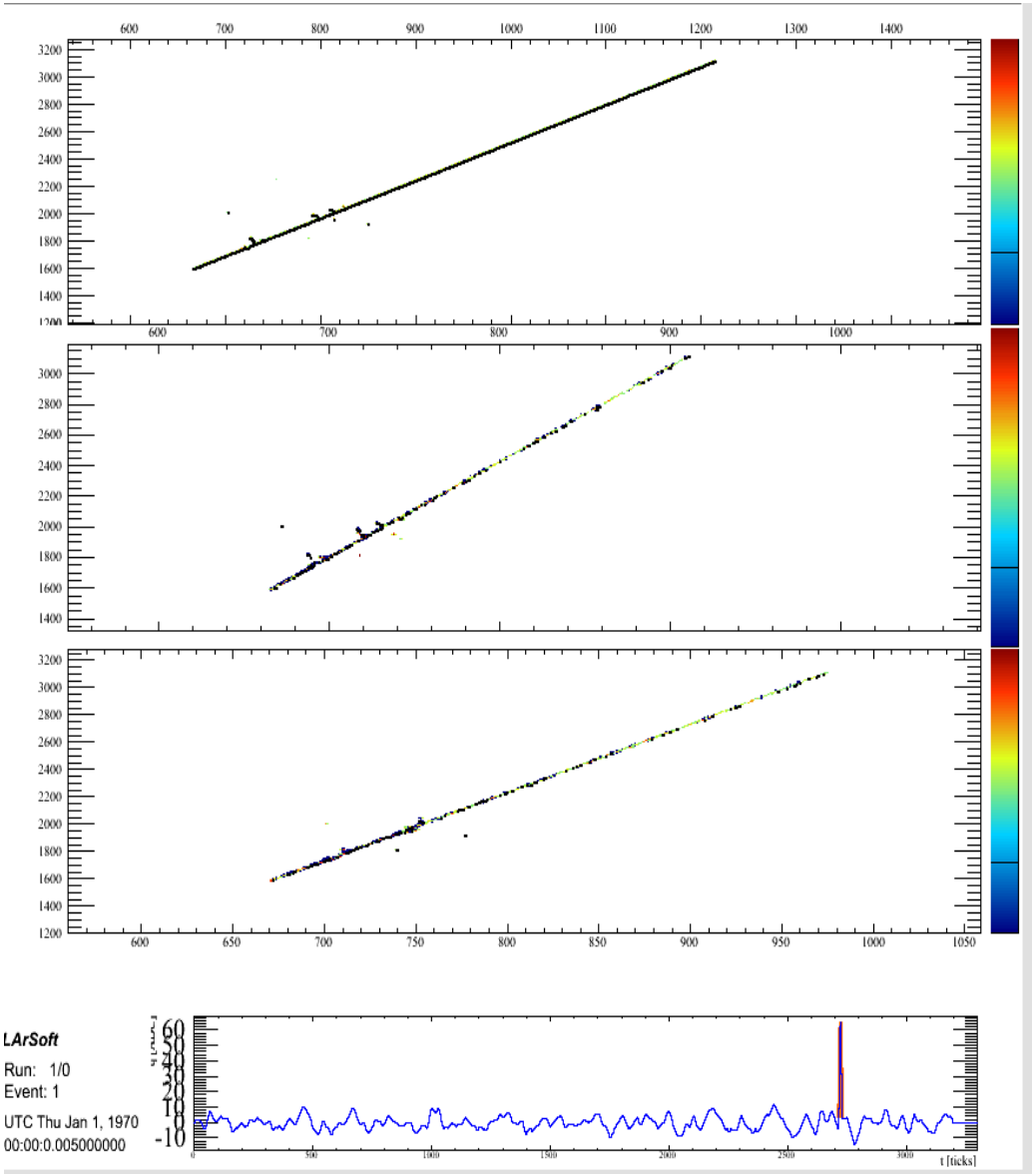
Collection (what can be implemented)

- Option 1: B.P. Signal shape + existing filter function
- Option 2: B.P. Signal shape + resulting filter function (induction)
- Option 3. Existing signal shape + existing filter.
- Tested 6GeV/c muons at 45deg, 10GeV/c showers and 0.6 GeV/c protons



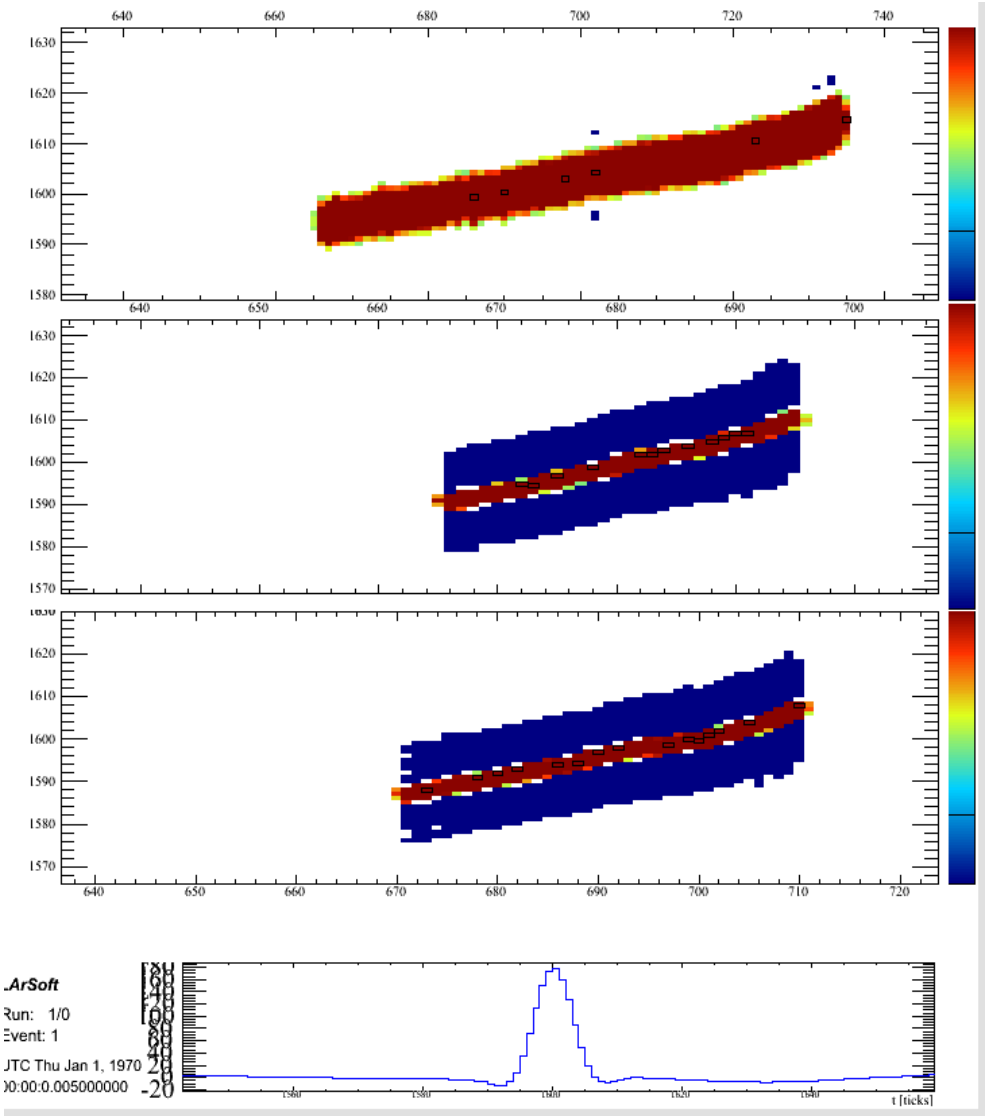


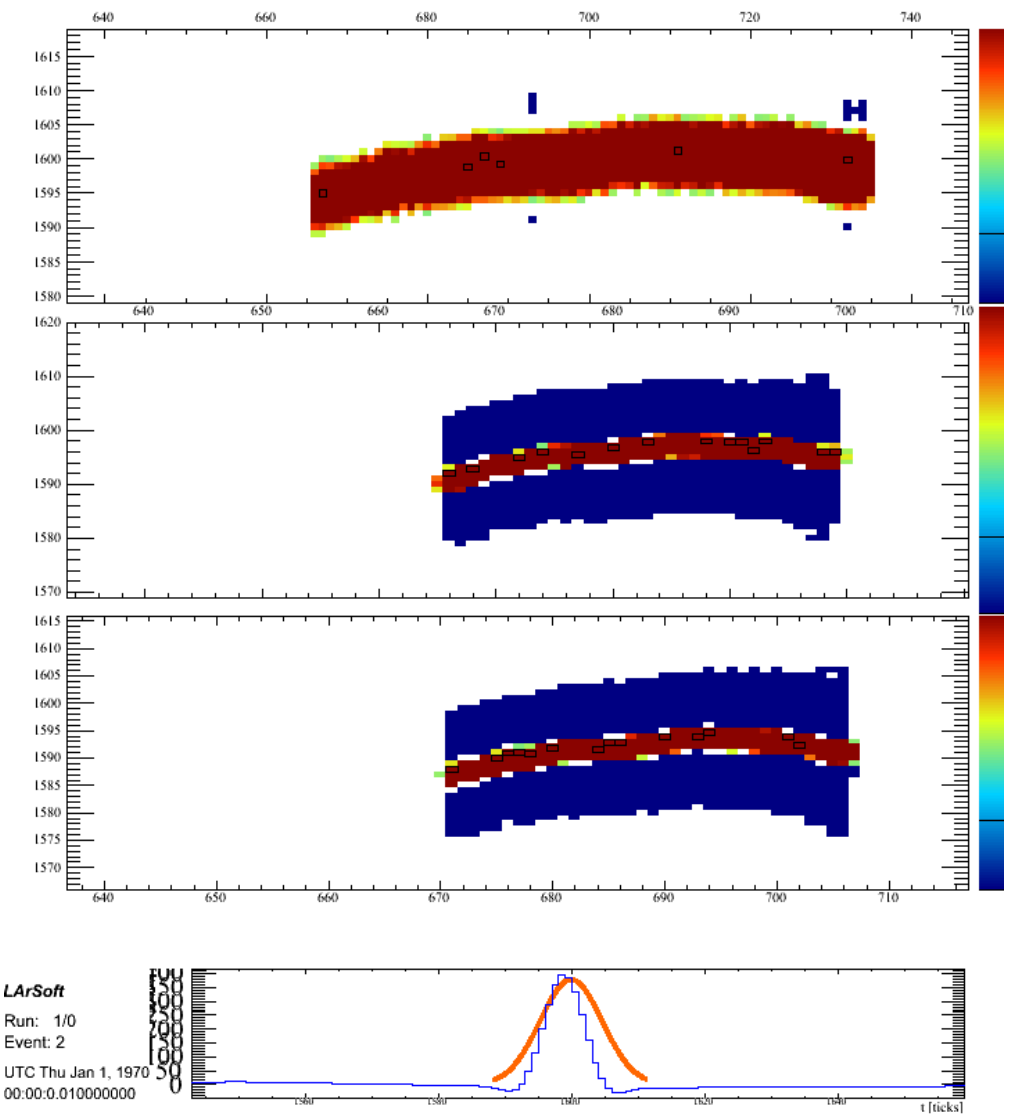
Option 1 (the good)



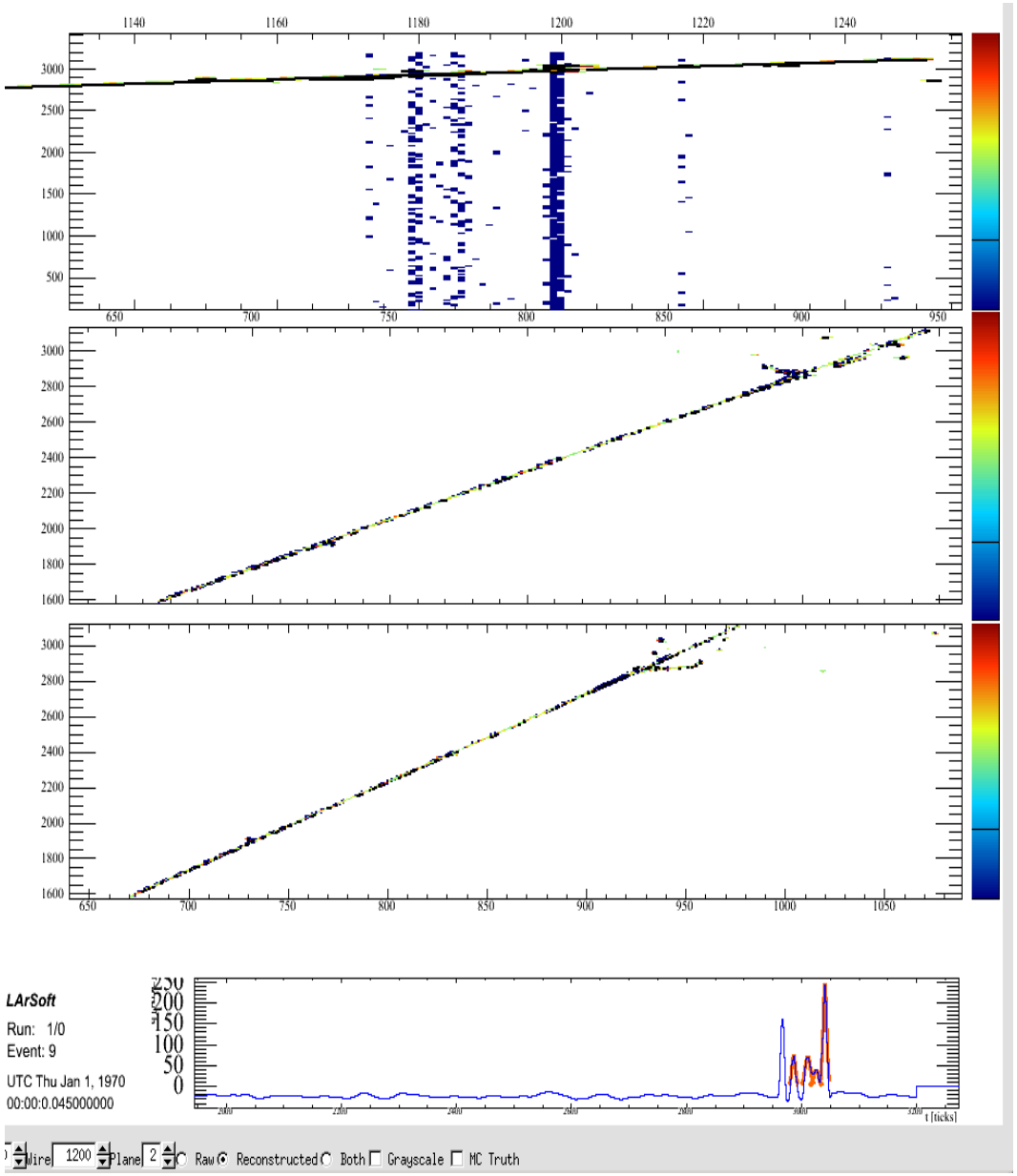
Muons in collection plane are mostly ok.

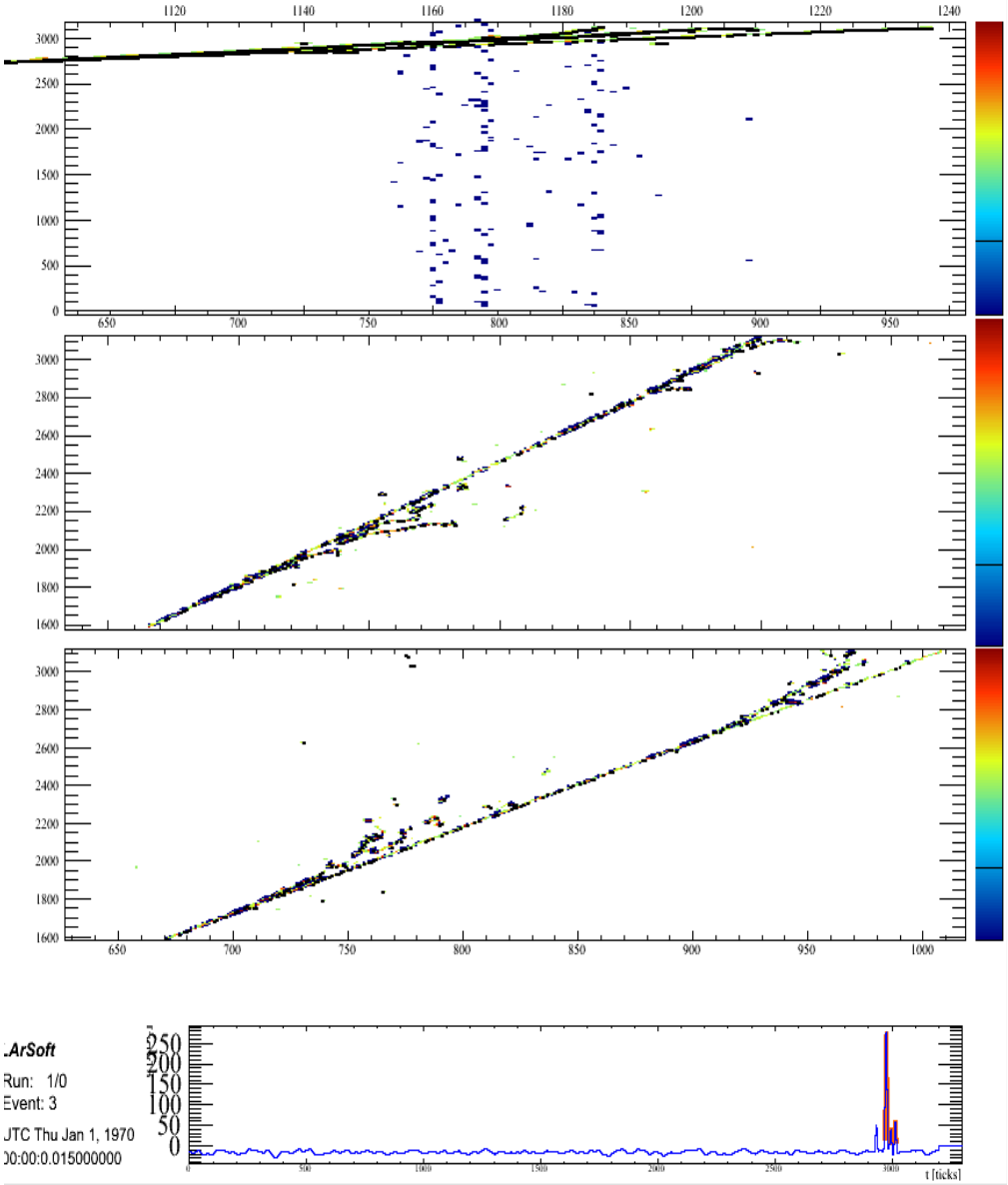
Option 1 (the bad)



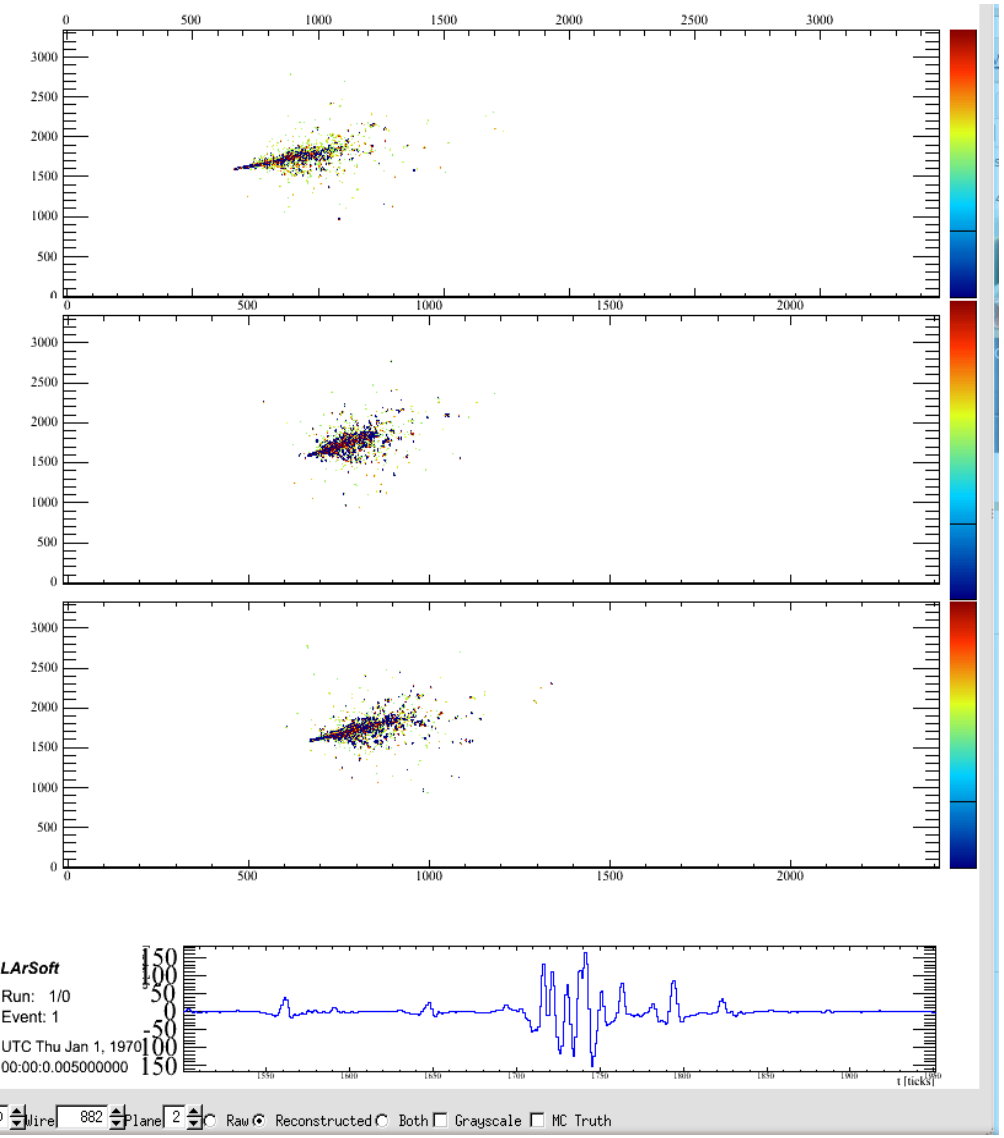


Option 1 (the ugly)





Option 2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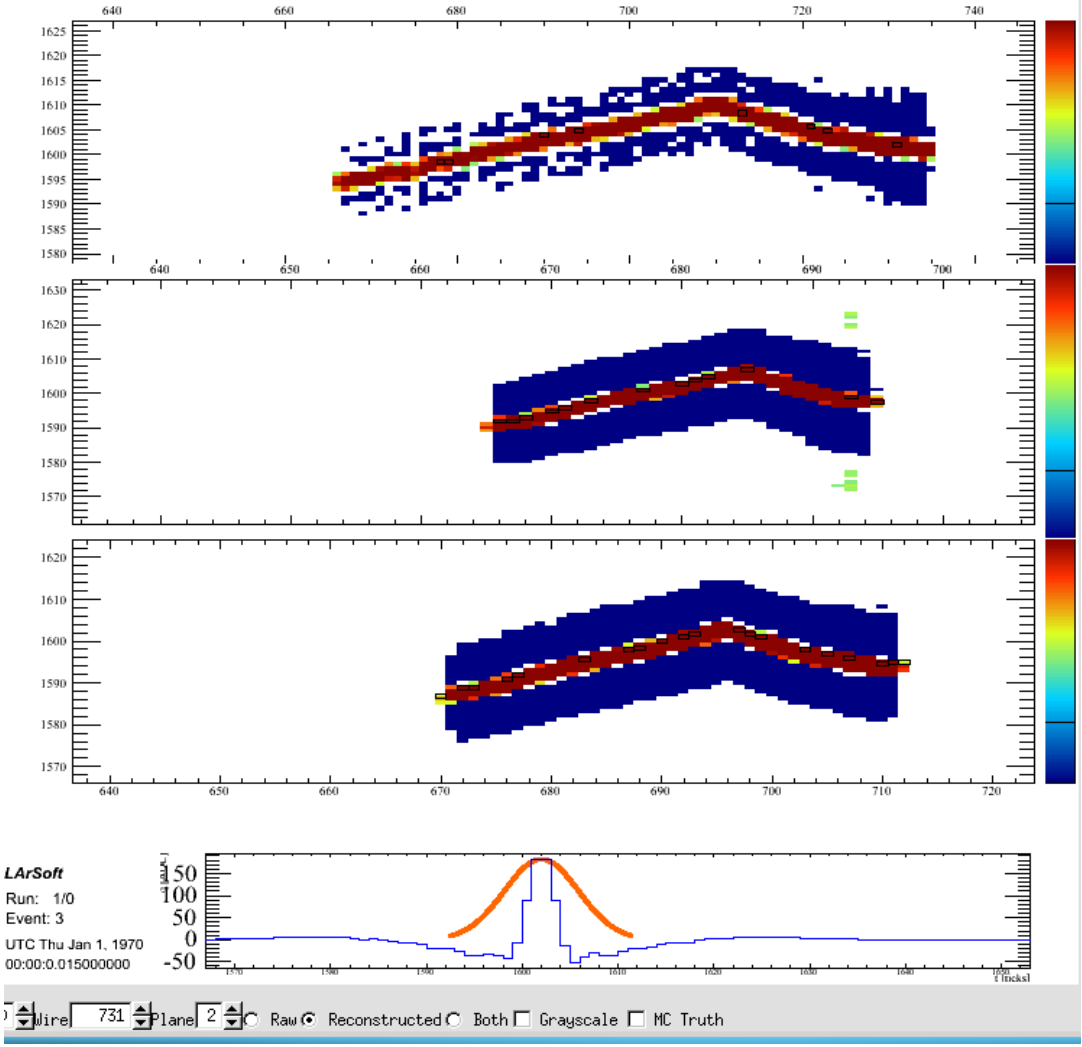
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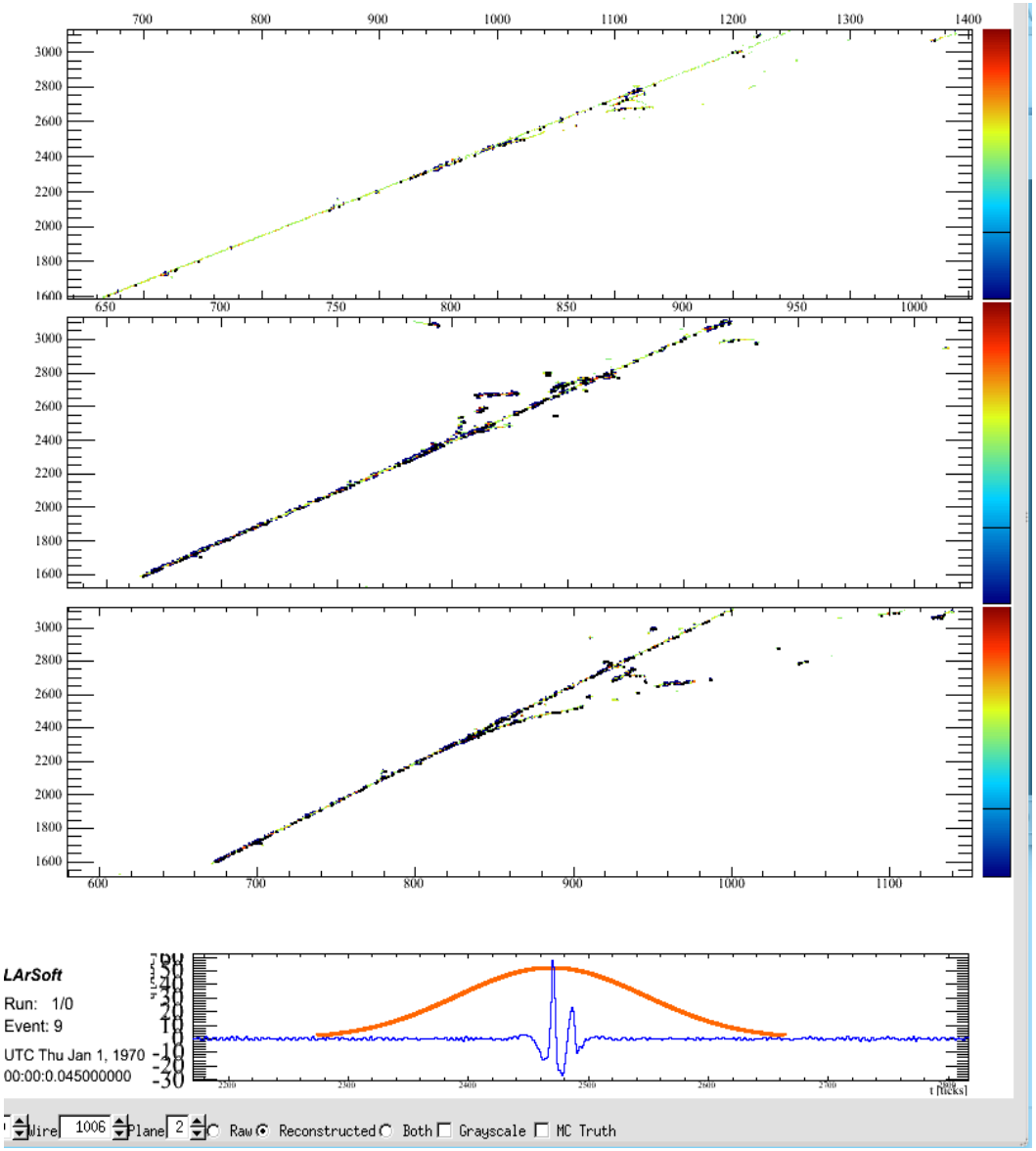
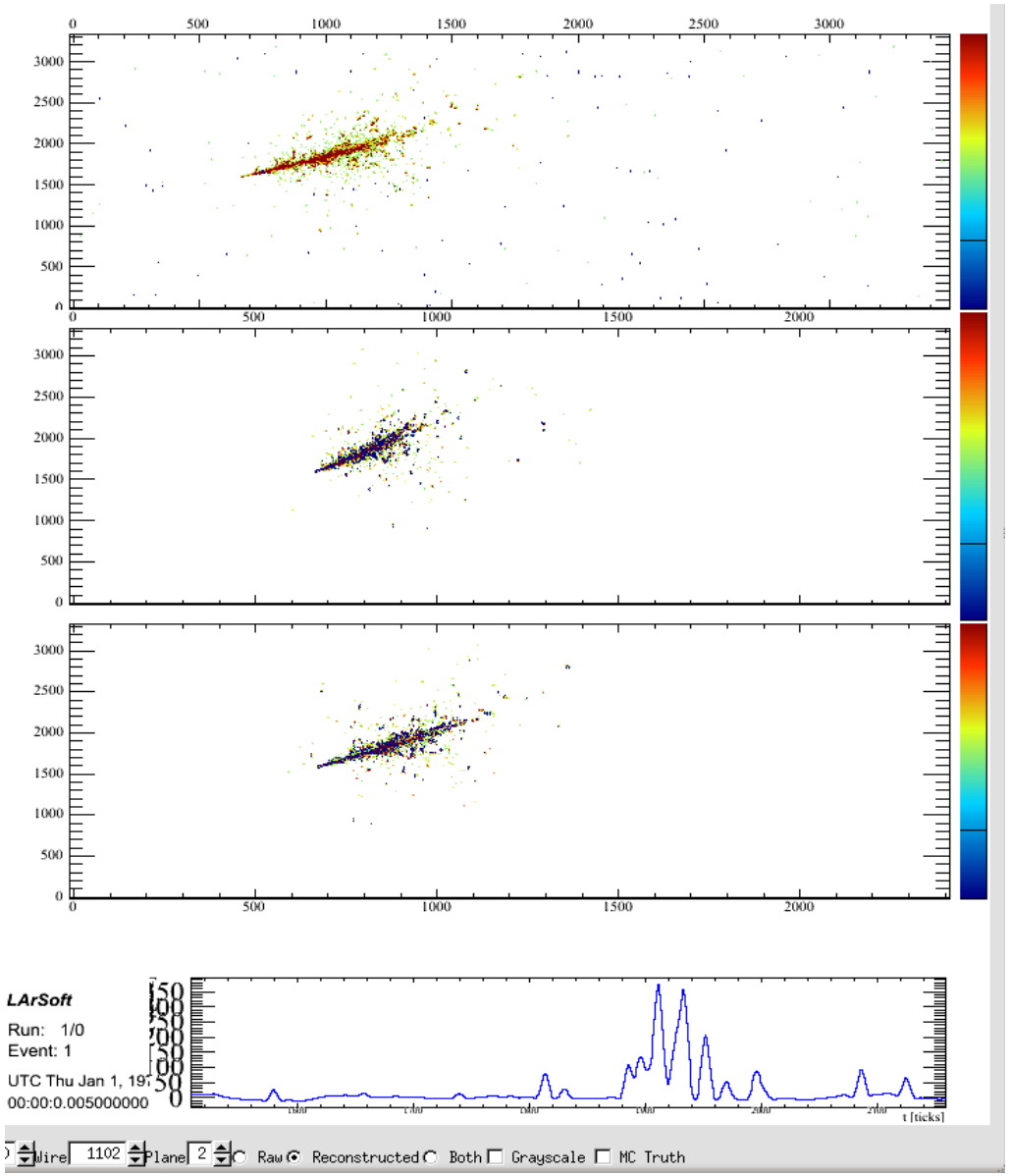
Wire 731 Plane 2 Raw Reconstructed Both Grayscale MC Truth

Option 2 (cont'd)



- Some of the bad hit finding here is also due to an effectively lower signal amplitude after applying the filter

Option 3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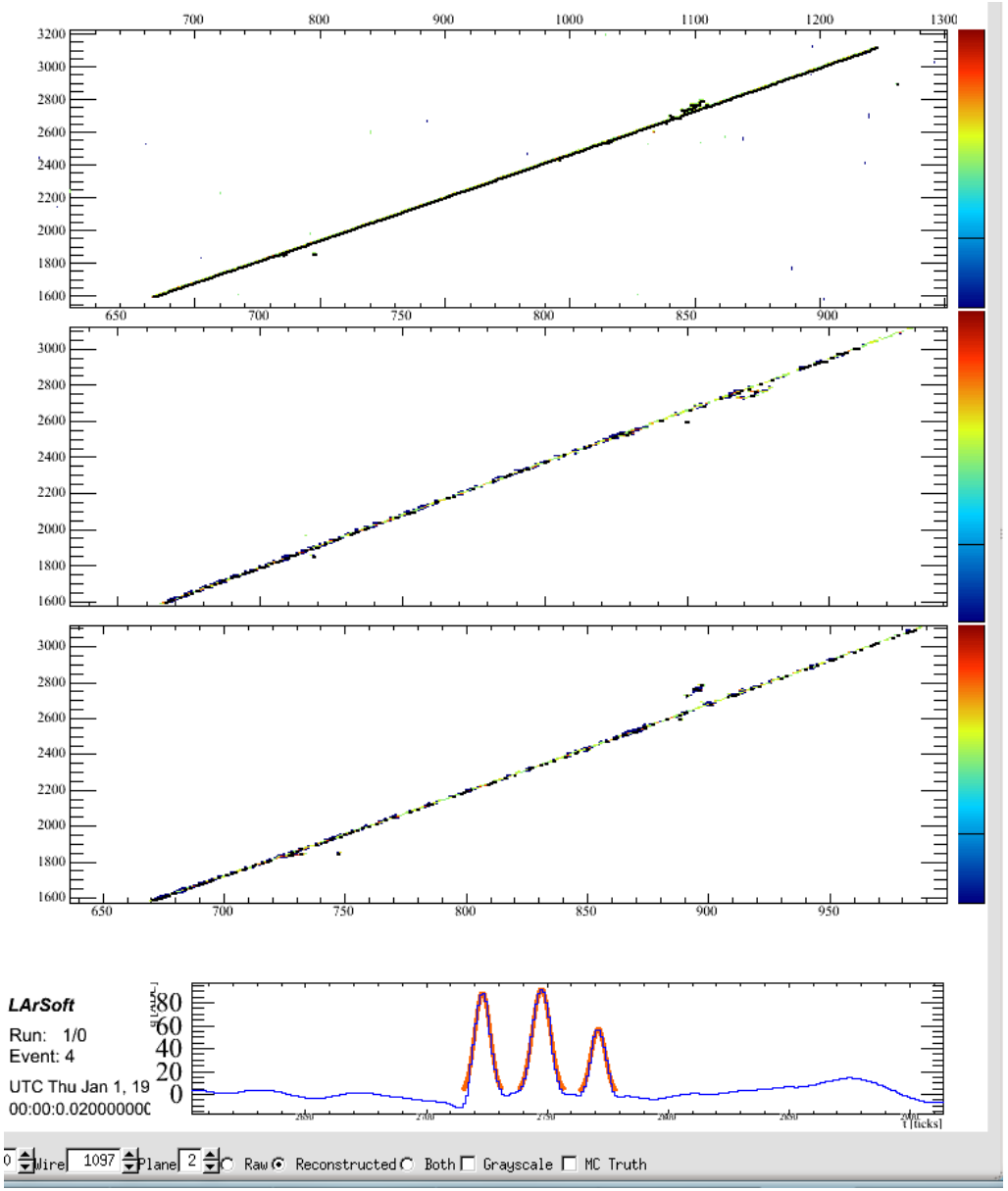
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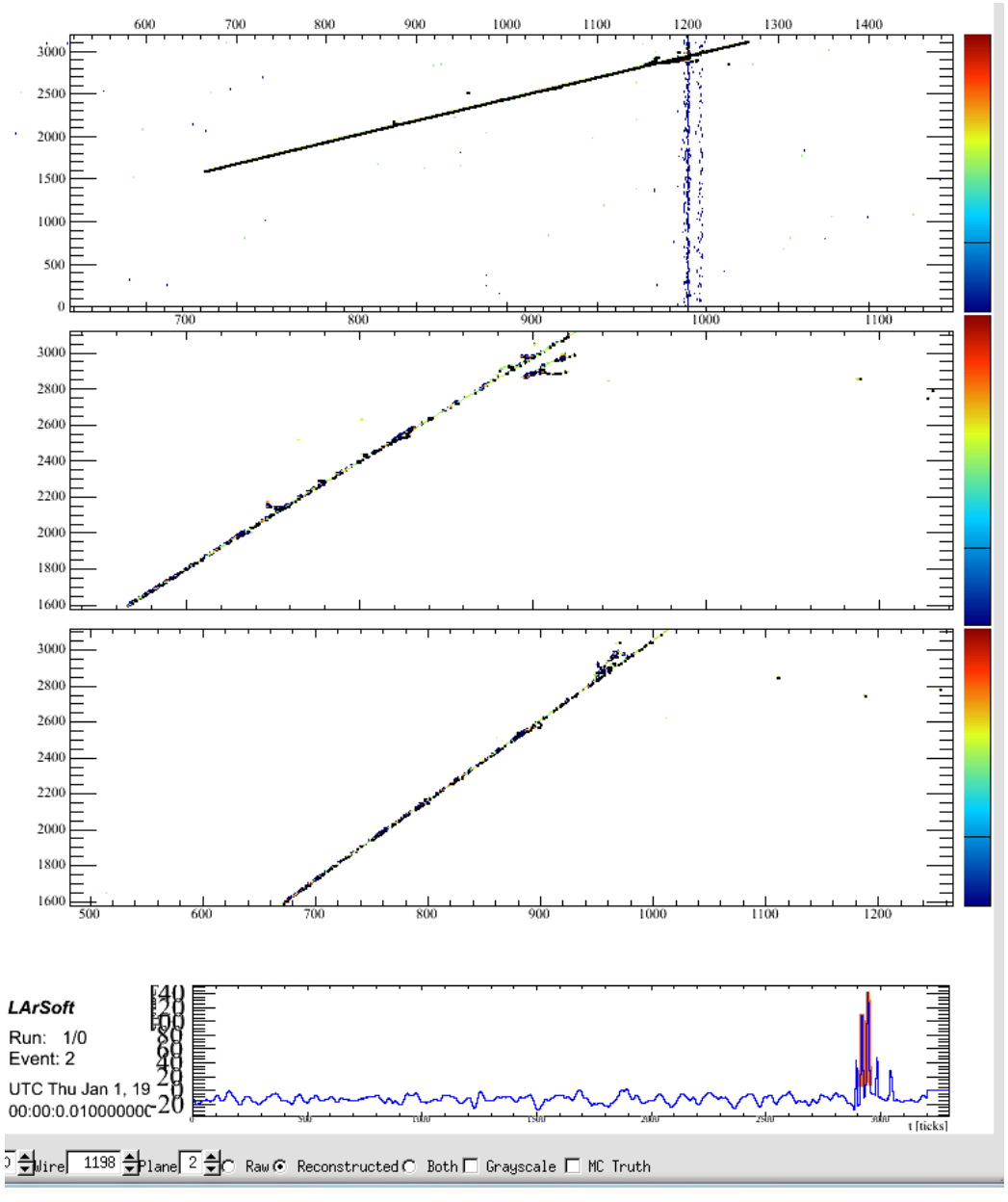
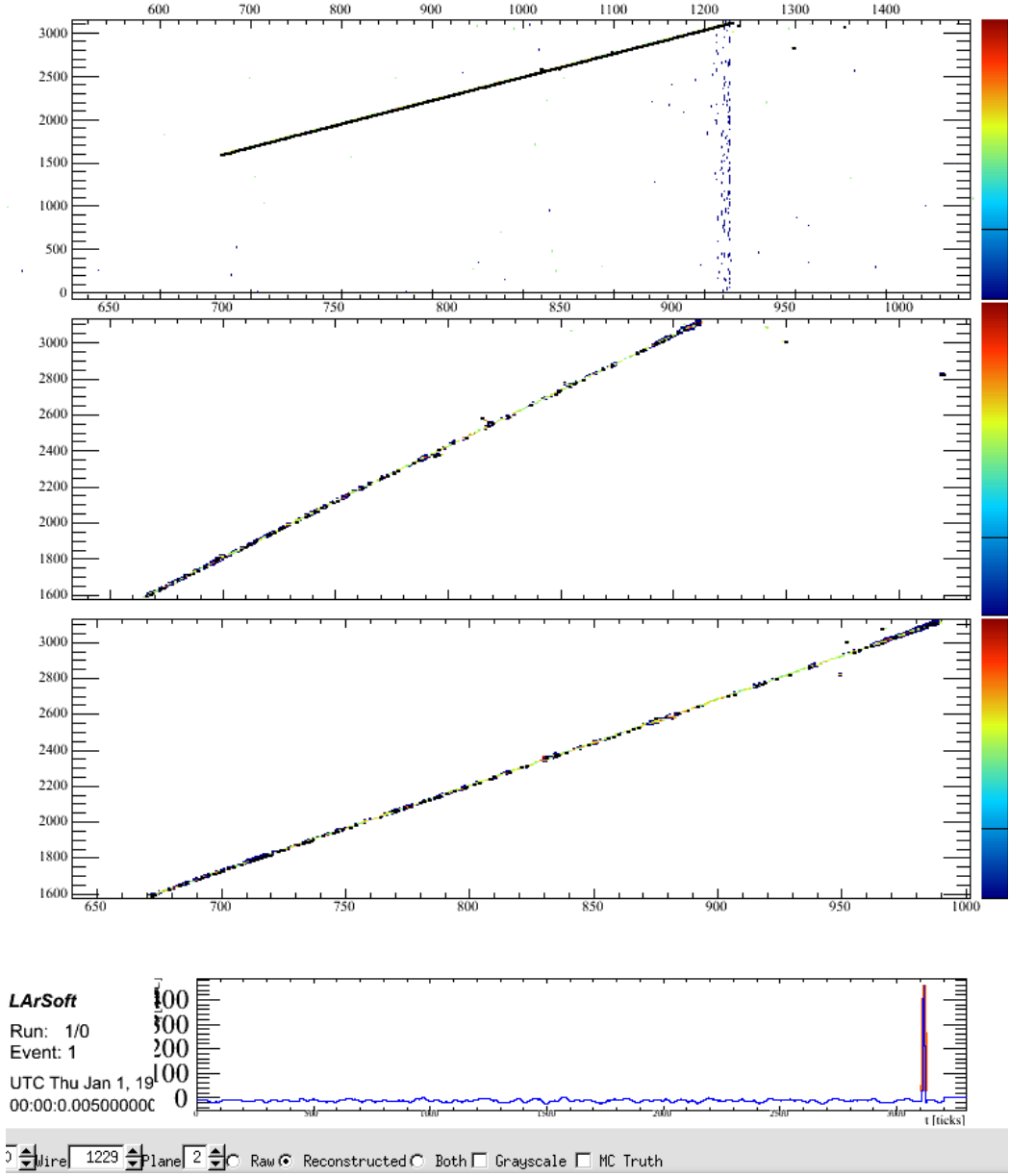
Wire 1097 Plane 2 Raw Reconstructed Both Grayscale MC Truth

Option 3 (cont'd)





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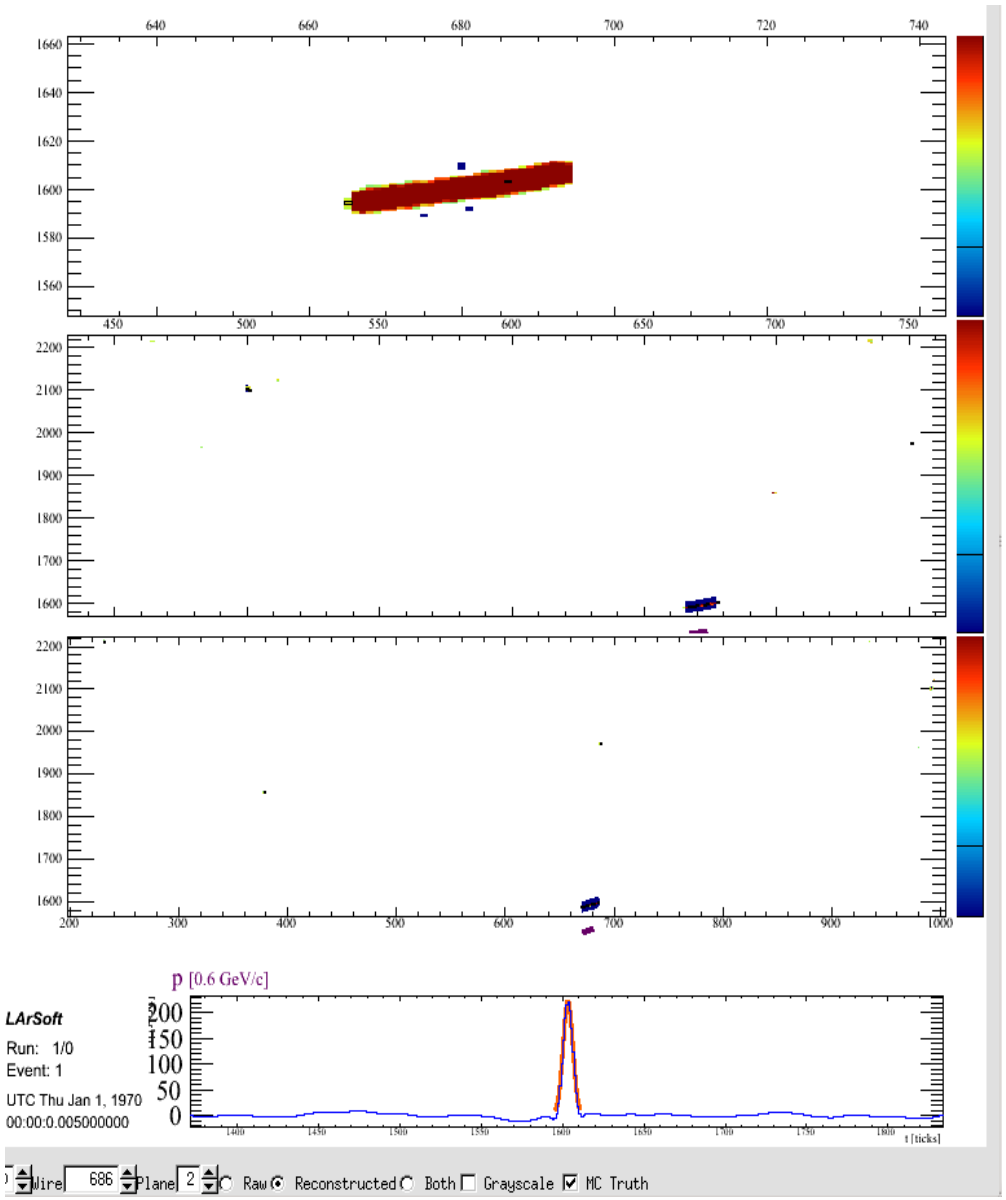
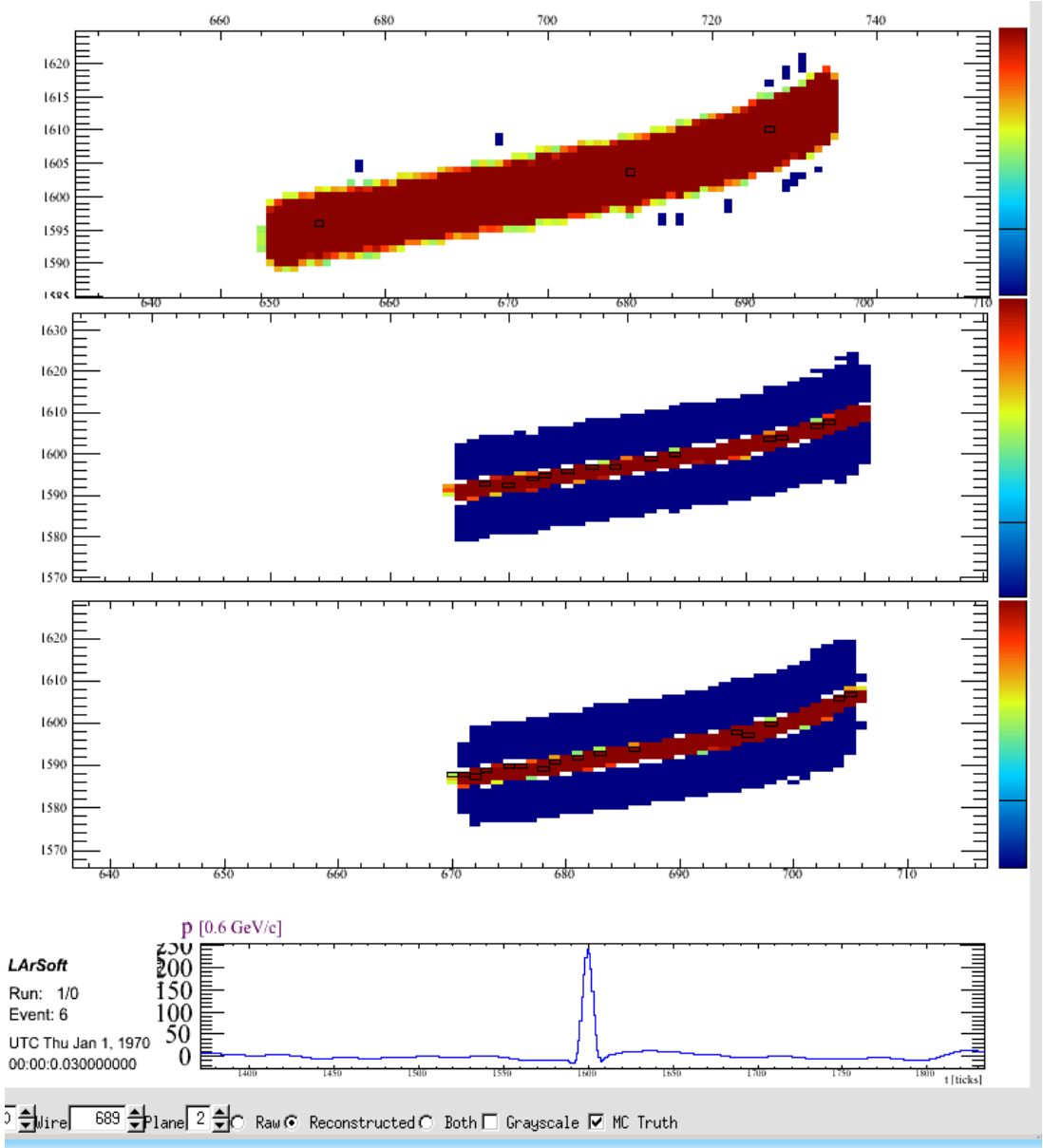
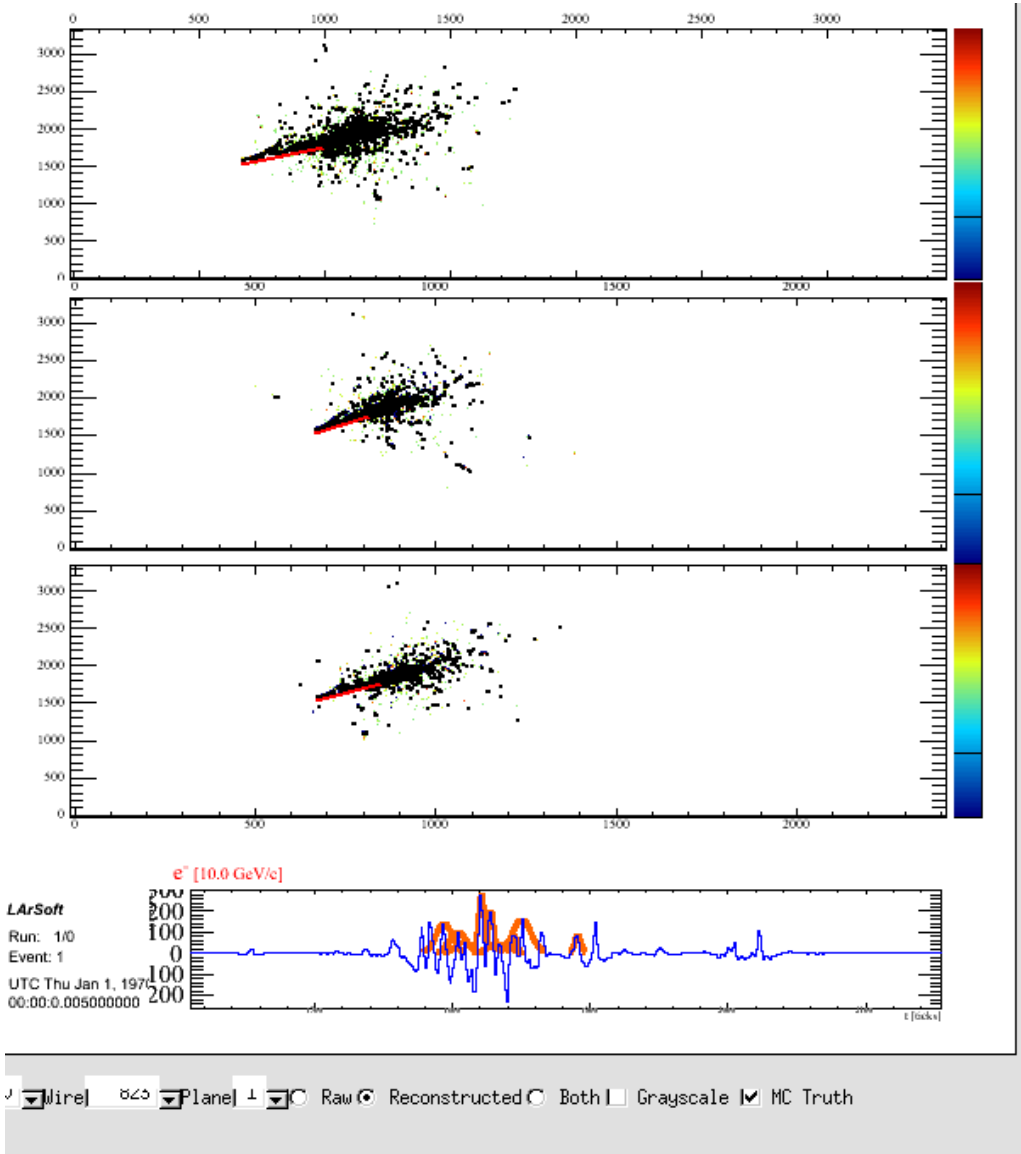
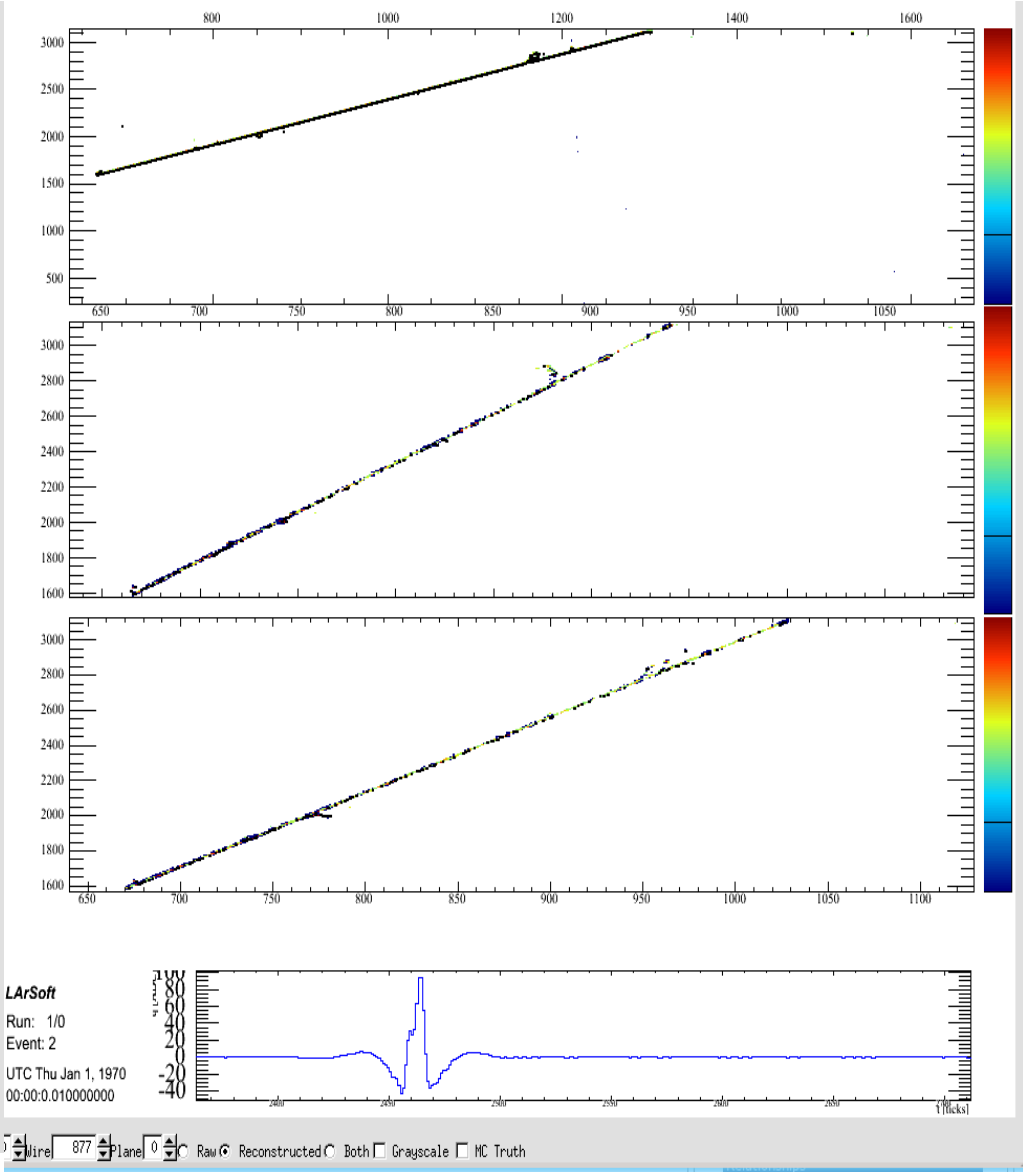


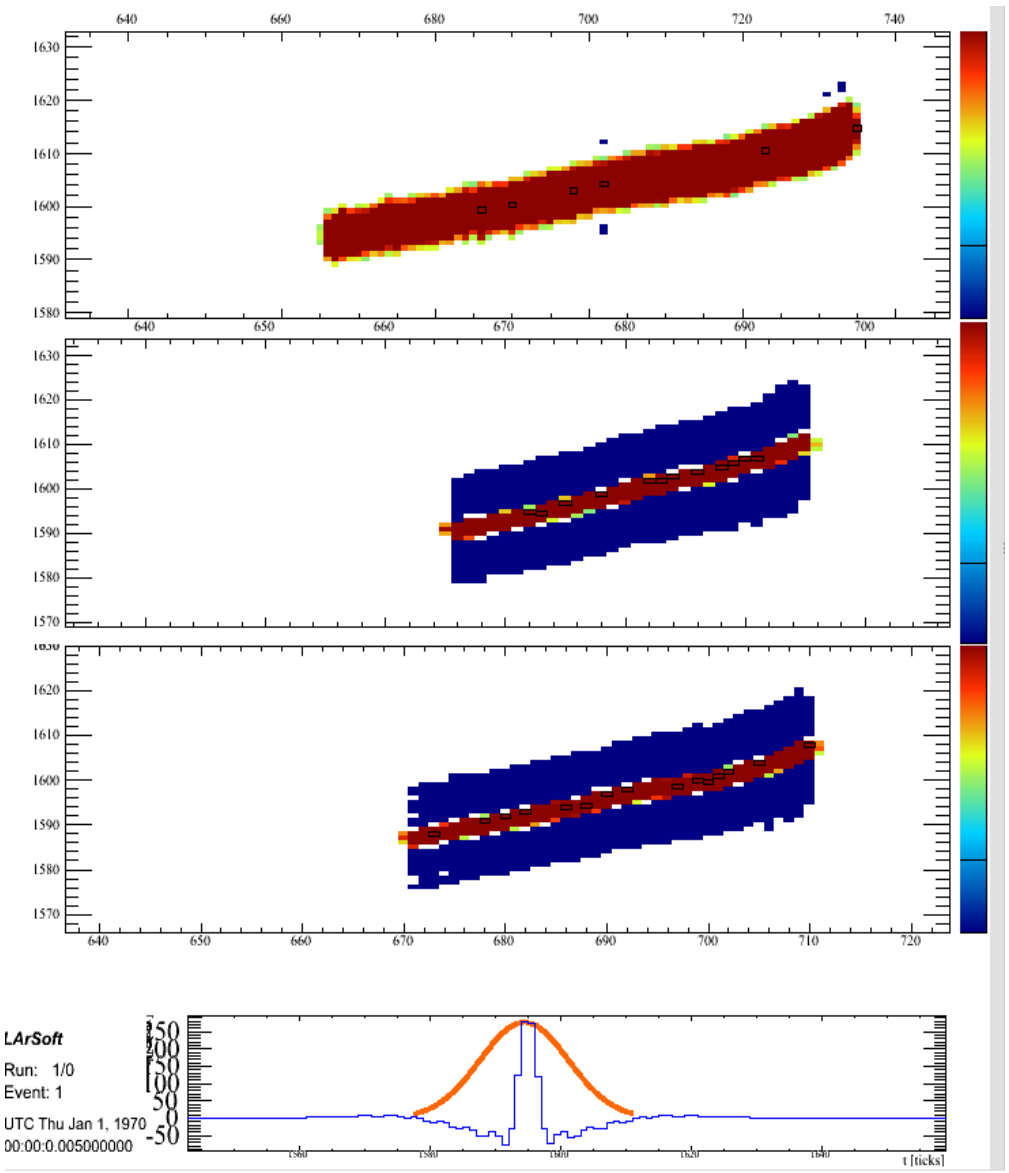


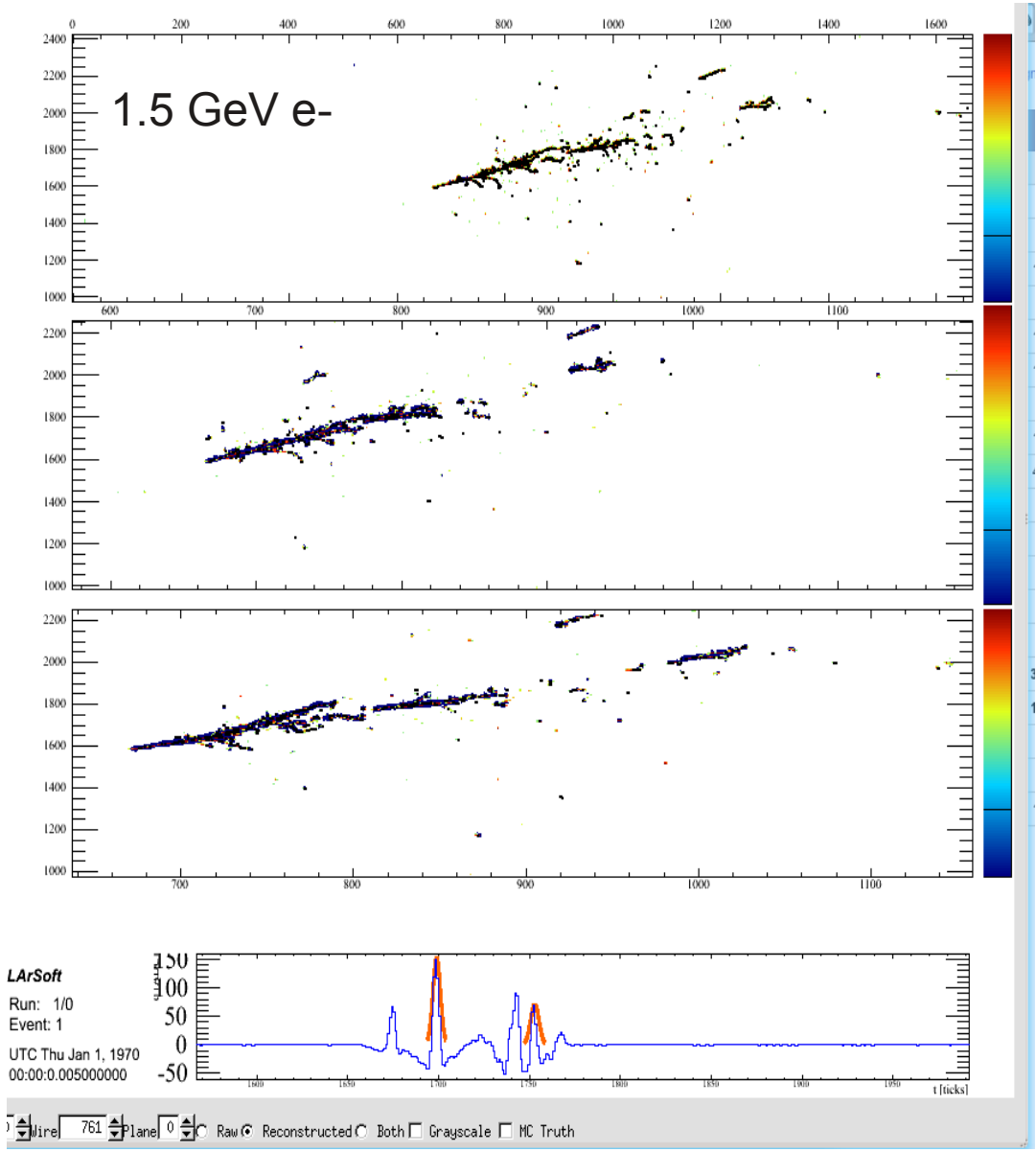
Induction Plane problems





Induction Plane problems (cont'd)





Technical Stuff

- In my local repository I have version of CalDataAna that calculated the Wiener filter on the fly. It is currently cheating, i.e. works on MC knowing, where the event starts. Could think to make it choose noise vs signal on amount of charge on channel. This could be automatized and used for data (offline repository?)
- Some of the induction problems may be due to the fact that the fitting function is slightly off at lower frequencies.
- I would consider using histograms for the filter functions – it could make the automatization process easier – take out the step of finding an appropriate fitting function. This does introduce extra files lying around (alternatively pickup histogram from DB?)
- Maybe insert more realistic noise parameters and spectrum from Prototype II test.

Conclusions

- The noise (+signal shape +filter function etc...) is almost ready to go. Need to tweak it some more.
- During the preparation of this talk I started doubting whether it should go into the frozen release, because:
  - It often causes trouble for hitfinder, so we need some time to test this before freezing it.
  - Need to recheck the normalization for calorimetry – this was difficult because of recent repository changes.
  - Unless we have more realistic noise – do we really gain something from it being inside? – does not affect truth studies.
- We can use this to set a new HitFinder Threshold for uBooNE – I'm guessing ~20 ADC looking at the display, but will tweak it more.